Ministry of Education and Science of Ukraine
V. N. Karazin Kharkiv National University

INSTRUMENTAL AND LABORATORY RESEARCH METHODS

Methodological recommendations
for independent work of 2nd year students of the medical faculty in the elective discipline "Instrumental and laboratory research methods"

Electronic resource

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Instrumental and laboratory research methods : methodological recommendations for
I 68 independent work of 2nd year students of the medical faculty in the elective discipline "Instrumental and laboratory research methods" [Electronic resource] / compilers S. O. Sherstyuk, M. O. Ivanenko, M. O. Fedorchenko. – Kharkiv : V. N. Karazin KhNU, 2025. – (PDF 130 p.)

Methodological recommendations for independent work of students in the discipline "Instrumental and laboratory methods of diagnosis" are developed in accordance with the current programs on instrumental and laboratory research methods for students of medical faculties of universities. The manual is intended for students' work during preparation for classes on the course "Instrumental and laboratory research methods". The topics are illustrated with drawings and diagrams that facilitate the perception of the material and contribute to its better assimilation. The materials allow students to form a correct understanding of the regularities of the structure and functions of the human body. For medical students.

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CONTENT

INTRODUCTION

Instrumental and laboratory diagnostic methods are examinations of internal organs using various mechanical devices. Modern medicine uses many instrumental diagnostic methods to establish an accurate diagnosis. Thanks to the latest achievements in the field of medical equipment and the impeccable work of specialists, unique examinations are carried out today. Almost all instrumental diagnostic methods are safe, so they can be carried out repeatedly and without harm to health. This discipline is designed to unite existing knowledge of human anatomy and physiology, to provide the highest understanding of the existence of biological matter, to form the basis of treatment tactics in the medical practice of a future doctor.

Instrumental and laboratory diagnostic methods

Specific objectives:

- To determine the general principles of instrumental and laboratory diagnostics in research;
- To analyze information about the structural and functional organization of human systems and organs;
- To determine the significance of laboratory research methods for the final conclusion in making a diagnosis;
- To interpret the patterns of homeostatic parameters of the body based on the conclusions of laboratory analysis;
- To study the methods of laboratory and instrumental diagnostics used in internal medicine and their information value.
- To be able to draw up a plan for examining a patient with a typical course of the most common therapeutic diseases and their complications.
- To master the methods of laboratory and instrumental examination.
- To identify the relationship between the pathogenesis of the disease and its clinical and instrumental manifestations.
- To study and be able to analyze, based on laboratory and instrumental examination methods, the nature and severity of disorders of the functions of vital human organs at each stage of the disease.
- To demonstrate mastery of moral and ethical principles of attitude towards a living person as an object of clinical research.
- To perform medical and research manipulations.

Topic 1. Laboratory diagnostics: various blood tests: general clinical, biochemical, urine and feces tests; cytological studies; bacteriological cultures. immunological, toxicological, hormonal and allergic panels, tumor markers, etc.;

Laboratory diagnostics for early detection of diseases or risk factors that help to avoid further progression of the disease or reduce the risk of its development. Be able to investigate the effect of toxic substances on the quantitative assessment of toxins or drugs in the body, which allows you to establish the cause of the disease or poisoning. Detect allergic reactions using an allergy panel that allows you to identify

specific allergens to which the patient may have an allergic reaction. Studies of tumor markers in the blood can serve as indicators of pathological processes occurring in the body and may be associated with cancer. Laboratory diagnostics is an integral part of medical practice, helping doctors make an accurate diagnosis, choose an effective treatment plan and monitor patients to ensure the best treatment outcome.

Topic 2. Flow cytometry. The basis of the flow cytometry method. Samples for flow cytometry. Principle of the method. Advantages of the method. Field of application: Immunology, Oncology, Cytology, Hematology, Pharmacology.

Introduction to the principles of flow cytometry, in particular, how lasers work, how cell parameters are measured and how data are analyzed. Learns the main cell markers used in flow cytometry and understands their significance for the identification and classification of different cell populations, be able to analyze the data obtained from flow cytometry and understand how to interpret the results to determine the characteristics of cells and their interactions. Identify the practical use of flow cytometry in various fields of medicine, such as immunology, oncology, hematology, cytology and pharmacology. Studying flow cytometry helps to develop research skills, such as formulating scientific questions, collecting data, analyzing results and preparing scientific reports.

Topic 3. Tomography methods: X-ray tomography (CT), magnetic resonance imaging (MRI), emission tomography (ET), ultrasound tomography, optical (optical coherence) tomography. General provisions, disadvantages, indications. General CT semiotics. X-ray diagnostics, angiography, general provisions, disadvantages, indications.

Principles of CT operation, including radiation dose distribution, the principle of operation of the X-ray detector and data processing for image acquisition. Mastering anatomical terminology for the correct interpretation of CT images. Learn to identify signs of pathological changes on CT images, which helps to establish a diagnosis and develop a treatment plan. Studying CT scanning protocols and procedures for various diagnostic tasks and patients with various indications. Be able to assess the quality of CT images and distinguish artifacts from real pathological changes. Learn to integrate the acquired knowledge and skills in working with real clinical scenarios and make informed decisions regarding diagnosis and treatment. Study of the possibilities and limitations of CT in comparison with other imaging methods, such as radiography, magnetic resonance imaging (MRI), etc.

Topic 4. Ultrasound diagnostics: organs and vessels of the abdominal cavity, kidneys, adrenal glands; pelvic organs in women, bladder and prostate gland; mammary glands; Doppler vascular imaging. Neurosonography. Ultrasound of the pyloric part of the stomach in newborns.

Ultrasound diagnostics to understand the principle of ultrasound diagnostics, in particular, how an ultrasound machine works, how to obtain images of organs and tissues, and how to interpret them. Studying the ultrasound anatomy of various

organs and systems of the body will help to recognize healthy structures and respond to deviations from the norm. Mastering the detection of various pathologies, such as tumors, inflammation, stones and other abnormalities, will allow you to distinguish pathological conditions and help in establishing a diagnosis. To study the relationship between ultrasound images and clinical symptoms, which will help to more accurately interpret the results obtained.

Topic 5. Functional diagnostics: ECG, 24-hour Holter ECG monitoring, 24-hour blood pressure monitoring (DMAP), measurement of CAT (central aortic pressure), spirometry, PH-metry and PH monitoring, rheoencephalography and rheovasography. Videogastroscopy, videocolonoscopy, videoendoscopy of ENT organs, colposcopy.

Methods of functional diagnostics, such as ECG, 24-hour Holter ECG monitoring, DMAP, spirometry, PH-metry, rheoencephalography and others. To understand the principles of operation of each method and their application for various pathological conditions. To acquire practical skills in using various devices and equipment for diagnostic procedures in order to learn to distinguish normal parameters in the results of research from pathological ones, as well as to know what changes occur in the body under the influence of various diseases and how to interpret them. To develop the ability to analyze the obtained diagnostic data and the ability to establish diagnoses based on them to provide optimal medical care to patients.

Topic 6. Nanotechnologies in the diagnosis of various diseases. Modern medicine in the latest dimensions: translational and personalized, targeted and integrative. The latest knowledge in the scientific world.

The study of nanotechnologies in the diagnosis of various diseases opens up new prospects for medicine and can significantly improve the diagnosis and treatment of various diseases, creating the first steps towards modern medicine in the latest dimensions. To study the interaction of nanoparticles with biological systems, the properties of nanomaterials and their potential applications in the diagnosis of diseases that allow detecting diseases at early stages and with high accuracy. The introduction of targeted therapies, i.e. research and development of methods for delivering drugs using nanoparticles for a more effective and precise impact on the disease and reducing negative side effects. This can increase the effectiveness of treatment and reduce the burden on patients and the healthcare system.

Topics of practical classes

№	Practical lesson topic	Number of hours
1	Laboratory diagnostics: various blood tests: general clinical, immunological, toxicological, hormonal and allergy panels, tumor markers, etc.; urine and stool tests; cytological tests; bacteriological cultures.	5
2	Flow cytometry. The basis of the flow cytometry method. Samples for flow cytometry. Principle of the method. Advantages of the method. Field of application: Immunology, Oncology, Cytology, Hematology, Pharmacology.	5
3	Tomography methods: X-ray tomography (CT), magnetic resonance imaging (MRI), emission tomography (ET), ultrasound tomography, optical (optical coherence) tomography. General provisions, disadvantages, indications. General CT semiotics. X-ray diagnostics, angiography, general provisions, disadvantages, indications.	5
4	Ultrasound diagnostics: organs and vessels of the abdominal cavity, kidneys, adrenal glands; pelvic organs in women, bladder and prostate gland; mammary glands. Neurosonography. Ultrasound of the pyloric part of the stomach in newborns.	5
5	Functional diagnostics: ECG, 24-hour Holter ECG monitoring, 24-hour blood pressure monitoring (BPMM), CAT (central aortic pressure) measurement, spirometry, PH metry and PH monitoring, rheoencephalography and rheovasography, vascular Dopplerography; Videogastroscopy, videocolonoscopy, videoendoscopy of ENT organs, colposcopy.	5
6	Nanotechnologies in the diagnosis of various diseases. Modern medicine in the latest dimensions: translational and personalized, targeted and integrative. The latest knowledge in the scientific world.	5
	Together	30

Tasks for independent work

№	Topic	Number of hours
1	Preparation for passing test tasks as components of the EDKI and USMLE RX on the topic: "Laboratory diagnostics: various blood tests: general clinical, immunological, toxicological, hormonal and allergy panels, tumor markers, etc.; urine and feces tests; cytological tests; bacteriological cultures." Preparation for a speech with a report on news in the scientific world on this topic.	10
2	Preparation for passing test tasks as components of the EDKI and USMLE RX on the topic: "Flow cytometry. The basis of the	10

	flow cytometry method. Samples for flow cytometry. Principle of the method. Advantages of the method. Field of application: Immunology, Oncology, Cytology, Hematology, Pharmacology." Preparation for a speech with a report on news in the scientific world on this topic.	
3	Preparation for passing test tasks as components of the EDKI and USMLE RX on the topic: "Tomography methods: X-ray tomography (CT), magnetic resonance imaging (MRI), emission tomography (ET), ultrasound tomography, optical (optical coherence) tomography. General provisions, disadvantages, indications. General CT semiotics. X-ray diagnostics, angiography, general provisions, disadvantages, indications." Preparation for a speech with a report on news in the scientific world on this topic.	10
4	Preparation for passing test tasks as components of the EDKI and USMLE RX on the topic: "Ultrasound diagnostics: organs and vessels of the abdominal cavity, kidneys, adrenal glands; pelvic organs in women, bladder and prostate gland; mammary glands. Neurosonography. Ultrasound of the pyloric part of the stomach in newborns." Preparation for a speech with a report on news in the scientific world on this topic.	10
5	Preparation for passing test tasks as components of the EDKI and USMLE RX on the topic: "Functional diagnostics: ECG, 24-hour Holter ECG monitoring, 24-hour blood pressure monitoring (DMAT), measurement of CAT (central aortic pressure), spirometry, PH metry and PH monitoring, rheoencephalography and rheovasography, vascular Dopplerography; Videogastroscopy, videocolonoscopy, videoendoscopy of ENT organs, colposcopy." Preparation for a speech with a report on news in the scientific world on this topic.	10
6	Preparation for passing test tasks as components of the EDKI and USMLE RX on the topic: "Nanotechnologies in the diagnosis of various diseases. Modern medicine in the latest dimensions: translational and personalized, targeted and integrative. Latest knowledge in the scientific world." Preparation for a speech with a report on news in the scientific world on this topic.	10
	Together	60

Topic 1. Laboratory diagnostics.

Over the past decades, laboratory diagnostics has made a huge step forward. Just 20 years ago, the main device for a general blood test was a light microscope and blood for this analysis was usually taken from a finger. It takes a doctor about 5-7 minutes to study 1 blood sample, blood cells must be counted and described by morphology (appearance - shape and size). Modern automatic hematological analyzers can do from 60 to 120 samples per hour.

CLINICAL BLOOD ANALYSIS

Clinical (general) blood test is the most common test that everyone has had to take at least once in their life. It is a clinical blood test that is most often prescribed at the first stage of any examination. It includes counting the amount of hemoglobin; the number of red blood cells (erythrocytes); white blood cells; leukocyte formula (each type of leukocytes is counted); blood platelets (thrombocytes); determination of erythrocyte sedimentation rate (ESR), etc.

This type of analysis reflects the general changes that occur in the body, is indispensable in the diagnosis of hematological, infectious, inflammatory diseases, assessment of the severity of the condition and the effectiveness of the therapy.

A complete blood count is widely used in examinations by many doctors to diagnose anemia, immunodeficiency, the presence of viruses and inflammatory processes in the human body, examines the condition of vascular cells. Some diseases, in the presence of other symptoms, are confirmed with almost 100% probability thanks to a complete blood count.

Clinical blood test

Know:

• Diagnostic capabilities of laboratory tests,

• Rules for preparing a patient who is sick for laboratory tests,

• Rules for collecting, storing and transporting biological material for laboratory research,

• Principles of laboratory research methods

• Diagnostic significance of laboratory research methods

• Possible deviations from the norm in some physiological and pathological processes.

Be able to:

• Write a referral to a patient for laboratory research,

• Ensure high-quality preparation of the patient for the study of biomaterial, its storage and transportation of material for research in the laboratory,

• Give a clinical assessment of the results of biological material research,

• Identify pathological changes in the composition and morphology of biological material in various pathologies.

Laboratory methods of blood research

Ensuring high quality hematological research is possible with standardization of preanalytical and analytical stages of work.

Preanalytical errors 68.2%

Analytical errors 13.3%

Postanalytical errors 18.5%

Factors affecting blood parameters

• physical and emotional stress
• seasonal, climatic, meteorological conditions
• time of day
• food intake
• smoking
• age
• gender
• patient activity and body position at the time of blood sampling.

Hemoglobin and hematocrit values in patients in the supine position are reduced by approximately 6%. Severe diarrhea and vomiting can lead to significant dehydration and hemoconcentration.

The influence of daily biorhythms on blood parameters

• bone marrow is most active in the morning
• spleen and lymph nodes around 5-8 p.m.
• maximum hemoglobin in the blood is observed from 11 a.m. to 1 p.m., and minimum from 4 p.m. to 6 p.m.;
• eosinophils are lowest in the morning between 9 and 11 a.m., peak eosinophils occur by 3 a.m.

Blood tests should be performed (except in emergency cases) at the same time to obtain comparable results

Collection and preparation of material for research

Blood collection

• The accuracy and correctness of the results are affected by the blood collection technique, the tools used in it (needles, scarifiers, etc.), the tubes in which the collection is carried out, and then storage and transportation occur.
• Standardization of the preanalytical stage through the use of standardized commercial consumables for taking, storing and transporting biosamples, standard reagents and diagnostic systems allows to significantly increase the reliability and accuracy of the study.

Blood for general clinical analysis is taken

• from a vein
• from a finger
• from the earlobe
• in newborns - from the heel

Blood testing is recommended to be carried out in the morning on an empty stomach, before physical exertion and various diagnostic procedures, taking medications, especially those administered parenterally.

Venous blood

The optimal method of blood aspiration is vacutainers (vacuum blood sampling systems):

• contain a certain strictly dosed amount of anticoagulant and provide standard conditions for aspiration of the entire blood volume,

• quick and high-quality blood sampling of the patient,
• reduction of blood sampling time by 30 - 50%,
• blood in the test tube is not subject to hemolysis,
• one venipuncture is enough to collect blood into several test tubes,
• there is no direct contact of the nurse or laboratory technician with the patient's blood, which ensures the prevention of viral infections that are transmitted parenterally.

Test tubes for obtaining blood serum

(immunochemistry, biochemistry, bacteriology, blood grouping)

1. With coagulation activator - red cap (black or white ring). The inner walls of the test tube are coated with a dry coagulation activator (SiO - silicon oxide) to accelerate the formation of a blood clot. Settling time 20-30 minutes.
2. With coagulation activator and separating olefin gel - red cap and yellow ring. During centrifugation, the gel forms a separating layer between the blood serum and the clot.
3. With coagulation activator and separating granules - red cap and red ring. Polystyrene granules form a separating ring between the serum and the blood clot during centrifugation.

Plasma collection tubes with EDTA (hematology, immunochemistry, genetic diagnostics)

With EDTA (ethylenediaminetetraacetic acid) purple cap, black ring. On the inner wall of the tube is applied dry EDTA-K2 or microdrops of EDTA-K3 solution at a concentration of 1.2-2.0 mg of dry reagent per 1 ml of blood. EDTA prevents blood clotting by blocking calcium ions. The tubes can be used in automatic hemoanalyzers without opening the cap.

With EDTA-K2 and olefin gel - purple cap and yellow ring. The gel separates formed elements and blood serum during centrifugation. The tubes are used to obtain serum for immunochemical determination of heat-sensitive analytes (ACTH, insulin, C-peptide, parathormone, homocysteine etc.)

Plasma tubes with heparin

(biochemistry, immunochemistry)

With heparin – green cap, black ring. Dry heparin (Li-heparin or Na-heparin) is applied to the inner wall of the tubes at a concentration of 12-30 IU per ml of blood. Heparin prevents the activation of the transition of

prothrombin to thrombin and stops the formation of fibrin from fibrinogen.
With heparin and olefin gel – green cap, yellow ring.

Test tubes for obtaining blood plasma with sodium citrate (coagulology)

With sodium citrate - blue cap, black ring. Plastic test tubes contain a buffer solution of sodium citrate (3.2% or 3.8%), which is used as an anticoagulant for coagulation studies. Sodium citrate, by binding calcium ions, prevents blood clotting.

Tubes for obtaining blood plasma for glucose determination

Tubes with anticoagulant and glucose stabilizer - gray cap, black ring. EDTA K3, K oxalate or Li-heparin are used as anticoagulants. Glycolysis inhibitors - sodium fluoride or monoiodoacetate stabilize blood glucose levels for up to 24 hours.

Tubes for obtaining blood plasma for ESR determination

Tubes with 3.8% sodium citrate - black cap and black ring. Blood to reagent ratio 4/1.
Venous blood

Taking blood with a syringe without an anticoagulant and then transferring it to a test tube is unacceptable:

– contact of blood with the walls of the syringe leads to the formation of platelet aggregates
– it is difficult to maintain an exact blood/anticoagulant ratio
– pressure in the needle increases the likelihood of hemolysis and blood splashing
– violation of the integrity and sterility of the sample
– - the likelihood of infection of personnel

Capillary blood

• **For hematological studies, capillary blood is recommended to be taken in the following cases:**

- with burns
- small or hard-to-reach veins
- severe obesity
- a tendency to venous thrombosis
- in newborns

• **EDTA** is the preferred anticoagulant when counting formed blood elements using automatic hematological analyzers. The concentration of EDTA in the collected blood should be constant and be 1.5 - 2.2 mg/ml of blood (for example, to obtain a ratio of 1.5 mg/ml, 0.04 ml of 7.5% K2EDTA or K3EDTA solution is poured into a test tube designed for 2 ml of blood). The lack of anticoagulant leads to

microcoagulation of blood and clot formation, an excess is the cause of an increase in the osmotic pressure of blood and shrinkage of cells. Some patients may experience a small spontaneous aggregation of platelets or, less often, the so-called EDTA-dependent pseudothrombocytopenia (immune in nature). The use of Na2EDTA is not recommended due to its poor solubility in blood.

• **Heparin** is the best anticoagulant for determining the osmotic resistance of erythrocytes and functional studies of leukocytes, including a number of tests with immunological markers. A feature of the action of this anticoagulant is the ability to maximally prevent hemolysis. Smears prepared from heparinized blood and stained according to Romanovsky have a bluish background.

• **Sodium citrate** is the anticoagulant of choice for studies of the blood coagulation system and platelet function.

The use of anticoagulants heparin or sodium citrate is accompanied by changes in the structure of cells and is therefore not recommended for the study of blood cell morphology; in addition, heparin does not prevent cell aggregation, so it is inappropriate to use it when counting leukocytes and platelets.

Delivery, storage and preparation of samples for examination

• Blood tests should be performed immediately after collection (the possibility of spontaneous platelet aggregation is excluded), or after 25 minutes (the time required for platelets to adapt to the anticoagulant) and no later than 6 hours after blood collection.

• If delayed analysis is necessary (transportation over long distances, technical malfunction of the device, etc.), blood samples are stored in a refrigerator (4° - 8° C) and examined within 24 hours. Blood cannot be frozen.

• Blood testing on the device is performed at room temperature. Blood stored in the refrigerator must be warmed to room temperature, since at low temperatures the viscosity of blood increases, and the formed elements tend to stick together, which, in turn, leads to impaired mixing and incomplete lysis. The study of cold blood can cause flagging during three-membered differentiation of leukocytes due to compression of the leukocyte histogram.

• When performing hematological studies at a considerable distance from the place of blood sampling, problems associated with adverse transportation conditions inevitably arise. The influence of mechanical factors (shaking, vibration, mixing, etc.), temperature disturbances, the likelihood of leakage and contamination of samples can affect the quality of the tests.

• To eliminate these reasons, it is recommended to use hermetically sealed plastic tubes or special transport isothermal containers when transporting blood tubes.

Clinical blood analysis includes determination of

• hemoglobin
• erythrocytes
• leukocytes
• leukocyte formula calculation
• determination of erythrocyte sedimentation rate
• platelets.

Analysis indicator	Norm
Hemoglobin	Men: 130-170 g/l
	Women: 120-150 g/l
Red blood cell count	Men: 4.0-5.0 • 10^{12}/l
	Women: 3.5-4.7 • 10^{12}/l
Leukocyte count	Within 4.0-9.0x10^{9}/l
Hematocrit	Men: 42-50%
	Women: 38-47%
Average erythrocyte volume	Within 86-98 μm³
Leukocyte formula	Neutrophils: •Segmentonuclear forms 47-72% •Rabdominal forms 1-6% Lymphocytes: 19-37% Monocytes: 3-11% Eosinophils: 0.5-5% Basophils: 0-1%
Platelet count	Within 180-320 • 10^{9}/l
Erythrocyte sedimentation rate (ESR)	Men: 3 – 10 mm/h
	Women: 5 – 15 mm/h

The normal hemoglobin concentration in women is 120 - 140 g/l, in men - 130 - 160 g/l.

Causes of increased hemoglobin

• Dehydration (reduced fluid intake, profuse sweating, impaired kidney function, diabetes mellitus, diabetes insipidus, vomiting or diarrhea, use of diuretics),
• Congenital heart or lung defects,
• Pulmonary or heart failure
• Kidney disease (renal artery stenosis, benign kidney tumors)
• Diseases of the blood-forming organs (erythremia).

Low hemoglobin - causes

•Anemia
•Leukemia
•Congenital blood diseases (sickle cell anemia, thalassemia)
•Iron deficiency
•Vitamin deficiency
•Body exhaustion
•Blood loss

Factors affecting the correct determination of the number of erythrocytes:

• Patient preparation
• Violations in blood collection technology
• high leukocytosis
• giant platelets
• erythrocyte agglutination
• cryoglobulinemia

• microcytosis

<u>Sources of errors</u> when counting erythrocytes in the counting chamber are:

• Inaccurate blood collection with a pipette.

• Formation of a clot that absorbs part of the cells and underestimates the result of the study.

• Insufficient mixing of the contents of the test tube before filling the chamber.

• Improper preparation of the chamber: insufficient grinding of the cover glass; uneven filling of the chamber, formation of air bubbles.

• Counting erythrocytes immediately after filling the chamber, without waiting 1 minute.

• Counting a smaller number of squares than required by the method.

• Poorly washed chamber, tubes, pipette, capillary for blood collection; insufficiently dried tubes and pipettes.

• Use of poor-quality diluting solution

ERYTHROCYTE COUNT (RBC) depending on age

newborns 5 - 7 x 10^{12}/l

1 month 4.5 - 5.3 • 10^{12}/l

3 months 3.8 - 4.6 • 10^{12}/l

6 months 3.8 - 4.6 • 10^{12}/l

12 months 3.9 - 4.7 • 10^{12}/l

up to 6 years 3.66 - 5.08 • 10^{12}/l

> 6 years (boys) 4 - 5.12 • 10^{12}/l

> 6 years (girls) 3.99 - 4.41 • 10^{12}/l

Morphological features of erythrocytes in pathology

Anisocytosis – erythrocytes of various sizes:

Normocyte – diameter 7.1 -7.9 μm

Microcyte – diameter < 6.5 μm – microcytosis

Macrocyte – diameter > 8 μm – macrocytosis

Megalocyte – diameter > 12 μm

Schizocytes (torn off erythrocyte particles) – diameter 2-3 μm Microspherocyte – decrease in diameter and increase in thickness

Poikilocytosis – change in the shape of erythrocytes:

Ovalocyte – oval-shaped erythrocyte

Acanthocyte – star-shaped erythrocyte

Stomatocyte – erythrocyte with a central lumen in the form of a “crescent”

Drepanocyte – sickle-shaped erythrocyte

Hypochromia – decrease in the content of Hb in individual erythrocytes

Hyperchromia – Increase in the thickness of the erythrocyte, without increasing the saturation of their Hb

Polychromatophilia – Insufficient accumulation of HB in erythrocytes with residual basophilic substance

Clinical significance of erythrocytosis

Clinical diagnostics

Erythrocytosis - an increase in the number of erythrocytes in the blood (more than $5.0x10^{12}$/l), possibly:
1. reactive (secondary or symptomatic)
2. tumoral (primary).

Clinical and diagnostic significance of

Erythrocytosis secondary (reactive, relative) erythrocytosis develops due to hyperproduction of erythropoietin in response to tissue hypoxia, the causes of which can be different (chronic obstructive pulmonary disease, congenital heart disease); tumors (kidney cancer, adrenal gland, hepatoma, adenoma and pituitary cyst); polycystic kidney disease, renal artery stenosis, hydronephrosis, etc.

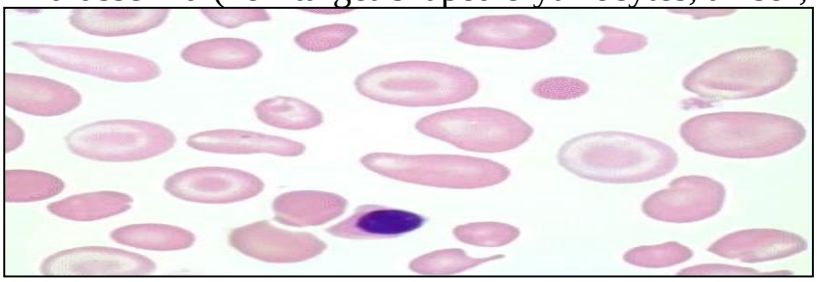
Develop in people with excess body weight, arterial hypertension and neurasthenia, with constant use of diuretics; in the post-infarction period in patients with coronary artery disease; with increased blood levels of carbon monoxide in smokers, prolonged adynamia, in particular in astronauts. Erythrocytosis, as a rule, does not reach very high numbers and is accompanied by slight reticulocytosis. In people who are in high altitude conditions or a long period of adynamia, hypochromia, slight anisocytosis and target-shaped erythrocytes may appear.

Clinical and diagnostic significance of erythrocytopenia

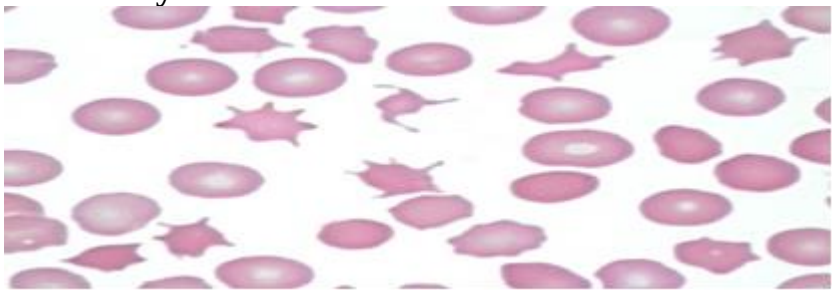
Erythrocytopenia - a decrease in the number of erythrocytes (less than 4.0x1012/l) per unit of blood volume. Erythrocytopenia can develop as a result of: blood loss, impaired hematopoiesis (aplastic anemia), increased hemolysis of erythrocytes (erythrocytopopathies, enzymopathy, hemoglobinopathy); radiation exposure; liver and kidney diseases; hypersplenic syndrome; deficiency of hematopoietic factors (iron, vitamin B12, folic acid);

hyperhydration with an increase in the volume of circulating plasma; infections, primarily chronic (tuberculosis).

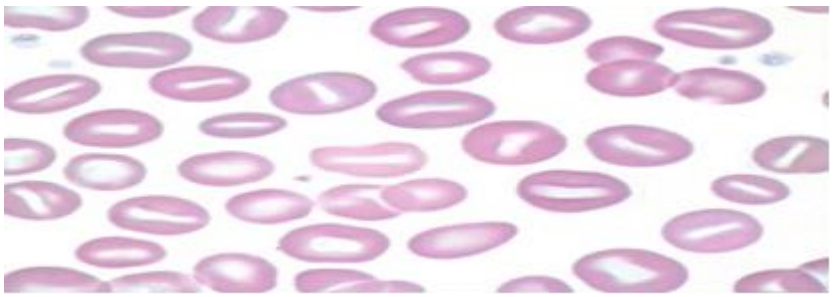
Thalassemia (non-target-shaped erythrocytes, aniso-, poikilocytosis)



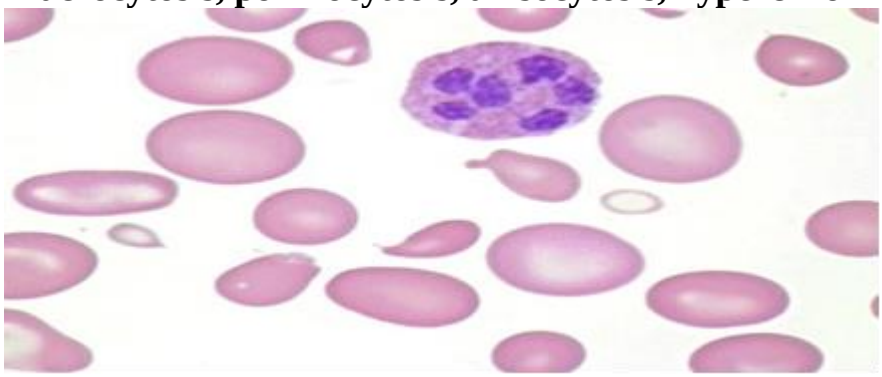
Acanthocytosis



Hereditary stomatocytosis



Macrocytosis, poikilocytosis, anisocytosis, hyperchromia



Hematocrit (hematocrit index)

• Hematocrit (Ht-hematocrit, hematocrit value) reflects the proportion of blood volume occupied by erythrocytes; expressed as a percentage or as an index in the SI system (l/l).

• The most common method is centrifugation of a blood sample with the addition of an anticoagulant in a standard capillary using hematocrit centrifuges and measuring the height of the erythrocyte column. The most convenient to use are commercial heparinized and non-heparinized hematocrit capillaries (Deltalab) of standards 75 mm, 70 mm and 30 mm.

• Most hematological analyzers provide for the determination of hematocrit.

Clinical and diagnostic value of determining the hematocrit value

• The hematocrit indicator is widely used to judge the degree of anemia, in which its decrease is usually noted, sometimes to significant figures (20 - 25%). The decrease in

hematocrit values in anemia occurs in parallel with a decrease in the number of erythrocytes and their size.

• An increase in hematocrit value (55 - 65%) is characteristic of erythremia, a less sharp increase (50 - 55%) is observed in symptomatic erythrocytosis, concomitant congenital heart defects, pulmonary insufficiency, and some hemoglobinopathies.

• ***The color index*** reflects the relative content of hemoglobin in the erythrocyte. An increase in the average hemoglobin content in one erythrocyte, and therefore the color index above 1.05 (hyperchromia of erythrocytes), is due to an increase in the volume of erythrocytes and occurs in B12 folate deficiency anemia

• Hypochromia of erythrocytes, i.e. a decrease in the hemoglobin content in erythrocytes (index below 0.85) is an indicator of insufficient saturation of erythrocytes with hemoglobin and occurs in iron deficiency and iron-refractory anemias.

• Normochromia (normal color index) is determined in healthy individuals, but can also occur in some anemias (normochromic anemias - acute posthemorrhagic, hemolytic, hypoplastic, metaplastic).

• ***The average Hb content in one erythrocyte (MCH-mean cell hemoglobin)*** is calculated by the formula:

$$MCH = \frac{Hb(g/l)}{\text{red blood cell count (million/μl)}}$$

• The result is expressed in picograms (1 picogram = 10^{-12}g). The average content of Hb in one erythrocyte ranges from 27 to 31pg.

• ***The average concentration of hemoglobin in the erythrocyte (MCHC-mean cell hemoglobin concentration)*** is calculated by dividing the hemoglobin concentration in g/100 ml by the hematocrit and multiplying by 100.

$$MCHC = \frac{\text{Hemoglobin (g/l)}}{\text{Hematocrit (\%)}} \times 100 \text{ (g/ml)}$$

• MCHC reflects the saturation of the erythrocyte with hemoglobin and is normally 30-38 g / ml. Unlike MCH, MCHC does not depend on the volume of cells and is a sensitive test for disorders of the hemoglobin formation process.

• ***Mean cell volume (MCV-mean cell volume)*** - can be calculated by dividing the hematocrit (erythrocyte volume) by the number of red blood cells per unit volume. MCV= Hct / RBC, measured in femtoliters (fl). MCV is a more objective parameter than a visual assessment of the diameter of erythrocytes. The normal value of this indicator is 80-95fl.

Causes of increased MCV:

– folic acid deficiency
– vitamin B12 deficiency
– reticulocytosis (acute blood loss, hemolytic anemia)
– liver cirrhosis
– chronic alcoholism
– rare causes include malignant neoplasms, myxedema, aplastic anemia

Causes of decreased MCV:

– chronic iron deficiency
– alpha and beta thalassemia
– anemia in chronic diseases (uremia, rheumatic diseases, severe chronic infections, etc.)

Causes of increased MCHC:

– Spherocytosis
– Intravascular hemolysis (free Hb in plasma) □□High titers of cold agglutinins

Causes of decreased MCHC:

– Chronic iron deficiency
– Anemia in chronic diseases

Calculate the color index

Hb – 96g/l, RBC-4.32x10^{12}/l (female)

Hb –146g/l, RBC-4.8x10¹²/l (male)
Hb –82g/l, RBC-3.5x10¹²/l (female)
Hb –135g/l, RBC-4.7x10¹²/l (male)

Factors affecting the accuracy of leukocyte testing

• cryoglobulinemia
• paraproteinemia
• normoblasts
• platelet aggregates
• unlysed erythrocytes
• long-term storage of blood at room temperature

Determination of the number of leukocytes in a counting chamber.

What is a Goryaev chamber - it is a thick glass slide with recesses, marked with 225 squares, 25 of which are also divided into 16 small squares. In small squares, erythrocytes were counted, in large ones - leukocytes. There was a formula according to which the number of cells was converted to volume, taking into account the dilution of the sample. Leukocyte counting under a microscope is carried out after lysing erythrocytes in 100 large squares of the counting grid and converted to 1 liter of blood, based on the volume of squares and blood dilution. Leukocyte counting should be done within 2-4 hours after blood collection.

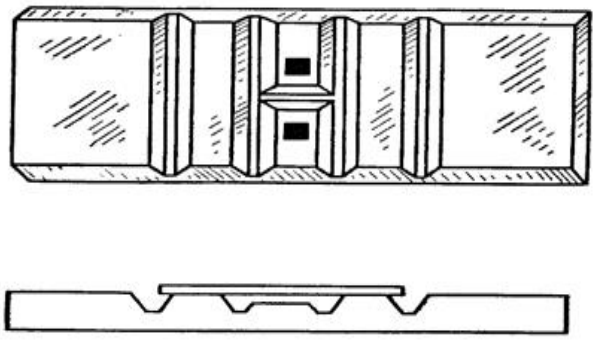
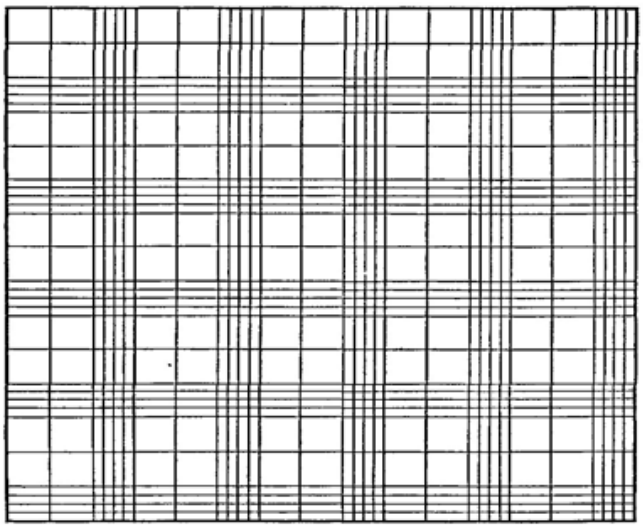
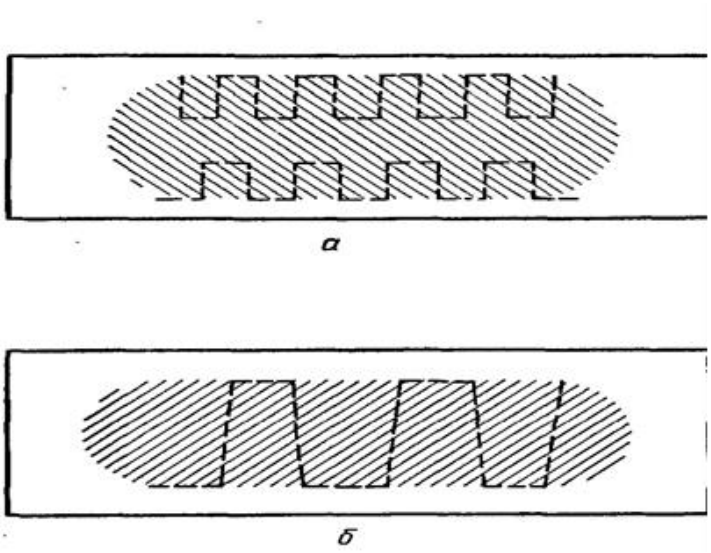


Рис. 37. Камера Горяева.

Pic.1 Goryaev's camera

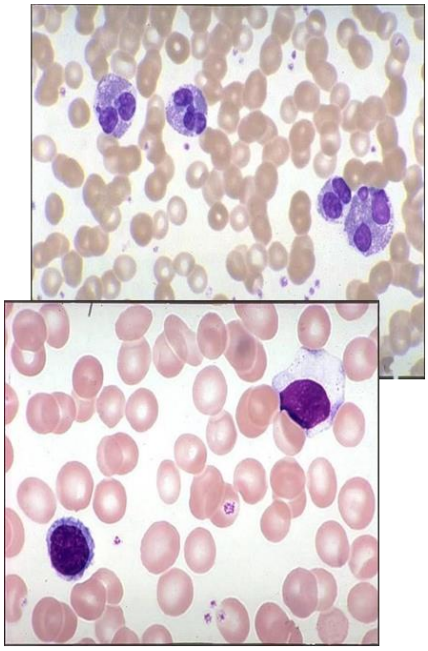
Pic. 2 Goryaev's grid

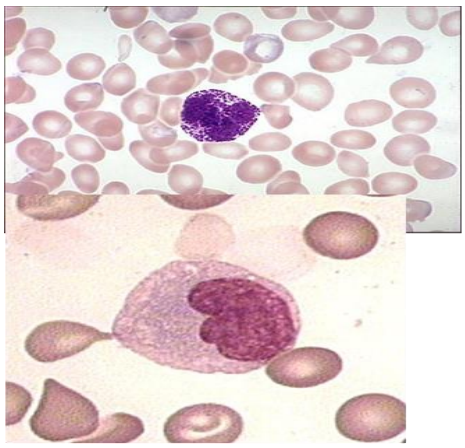




Pic. 3 Technique for calculating the leukocyte formula

The main sources of errors when counting leukocytes in the chamber:
• Incorrect ratio of blood and acetic acid volumes taken into the test tube.
• Incorrectly prepared acetic acid solution (at a concentration of more than 5%, some leukocytes may lyse, which will lead to an underestimation of the result).
• Prolonged exposure of the sample at a temperature above 28°C, which can accelerate the lysis of leukocytes in the sample and lead to an underestimation of the result.
• Incorrect filling of the Goryaev chamber. As with the counting of erythrocytes, the chamber must be left for 1 minute for the cells to settle.
• The Goryaev chamber is not washed well enough after the previous determination. Leukocytes remaining in the chamber may overestimate the results
Morphology of basophils, monocytes, eosinophils, lymphocytes





Morphological study of blood smears

Technique for preparing a smear on a glass slide

• A clean, degreased glass slide is used, preferably 1 mm thick (Gem company).

• A drop of blood is placed in the middle of the glass 1-2 cm from one of the ends.

• The ground glass, with which the smear will be made, is placed on the glass slide at an angle of 30-45 degrees 1-2 mm in front of the drop and moved slightly back so that the glass comes into contact with the drop of blood and the drop spreads along the corner between the two glasses.

• Then the ground glass slide is quickly moved forward, which should already be a slide or a special plastic spatula (Gem company, JSC UNIMED), which allows you to obtain a monolayer smear almost along its entire length.

• The smear should be 3-4 cm long. Do not press hard on the glass, as this will injure the formed elements of the blood.

• Smears are air-dried and labeled.

Staining of blood smears

The most commonly used staining methods are

• Romanivskyi

• Nokht

• Pappenheim-Kryukov

There are automatic devices for preparing and staining smears, which allow standardizing conditions and improving the quality of preparations.

• Currently, a wide range of high-quality dyes is offered (Gem company, Abris + NVF), which are easy to use and give good results when staining smears. You can use kits for rapid staining of blood smears within 20-30 seconds (Gem company).

• Automatic fixation and staining of smears can be carried out using special devices: "Gema-Tek" (USA), "POMK-1" (Russia), into which unfixed smears are loaded. Further automatic dosing of fixative-dye and buffer solutions ensures standard and uniform staining of smears.

Blood smear examination.

• The stained blood preparation should first be viewed using an immersion objective (90x) and a 7x or 10x eyepiece. Using a 10x magnification allows you to assess the appropriate cellular distribution, the approximate number of leukocytes in the smear. When examining erythrocytes, it is important to detect deviations in their size, shape, degree of saturation and distribution of hemoglobin, as well as the presence of

inclusions. Then the number and morphology of platelets are assessed, as well as the morphology and differential count of leukocytes.

• ***Differential count of leukocytes***

• The calculation of the leukocyte formula consists in registering all leukocytes found in the field of view, separately according to their belonging to certain germs.

• In a blood smear, the distribution of formed elements is uneven, since leukocytes differ in their physical properties (size, specific gravity, elasticity, etc.). Neutrophils, monocytes, eosinophils are most often found at the edges of the preparation, and lymphocytes in the middle. Therefore, the glass must be moved in a certain order. Several fields of view are counted along the edge, then returned to the center, etc. along a toothed trajectory.

• When calculating the leukocyte formula, keyboard laboratory counters are used. 100 cells are counted, followed by the output of the percentage, and if necessary, the absolute number of cells, based on the total number of leukocytes. In the case of pathology, at least 200 cells are analyzed, with special attention paid to qualitative changes in erythrocytes, platelets and leukocyte morphology.

Types of leukocytes, norm

Neutrophils	Segmentonuclear forms 47- 72%
	Rodular forms 1-6%
Eosinophils	0,5-5%
Basophils	0-1%
Monocytes	3-11%
Lymphocytes	19-37%

Neutrophils

Mature forms – segmented neutrophils.

Immature forms – rod-shaped. Normally, the number of rod-shaped neutrophils is minimal (1-3% of the total number).

Neutrophilia.

Reasons for increased neutrophil levels

1. Infectious diseases (angina, sinusitis, intestinal infection, bronchitis, pneumonia).
2. Infectious processes – abscess, phlegmon, gangrene, traumatic injuries of soft tissues, osteomyelitis.
3. Inflammatory diseases of internal organs: pancreatitis, peritonitis, thyroiditis, arthritis.
4. Heart attack (heart attack, kidney, spleen).
5. Chronic metabolic disorders: diabetes mellitus, uremia, eclampsia.
6. Cancerous tumors.
7. Use of immunostimulating drugs, vaccinations.

Neutropenia

Causes of decreased neutrophil levels

Infectious diseases: typhoid fever, brucellosis, influenza, measles, chickenpox (chickenpox), viral hepatitis, rubella).

Blood diseases (aplastic anemia, acute leukemia).

Hereditary neutropenia.
High levels of thyroid hormones (thyrotoxicosis).
Effects of chemotherapy.
Effects of radiotherapy.
Use of antibacterial, anti-inflammatory, antiviral drugs.

Shift of the leukocyte formula to the left

This means that young, "immature" (rod-nucleated) neutrophils appear in the blood, which are normally present only in the bone marrow, but from the blood.
It is observed in mild and severe infectious and inflammatory processes: angina, malaria, appendicitis, diphtheria, pneumonia, scarlet fever, typhus, sepsis, intoxication, acute blood loss.

Right shift of the leukocyte formula

Increase in the number of "old" neutrophils (segmented nuclear).
1. in healthy people living in areas contaminated with radiation waste.
2. with B12 - deficient anemia,
3. with folic acid deficiency, 4. in people with chronic lung disease or obstructive bronchitis.

Reasons for increased blood eosinophils

• Allergy (bronchial asthma, food allergy, pollen allergy and other allergies, atopic dermatitis, allergic rhinitis, drug allergy).
• Parasitic diseases – intestinal parasites (giardiasis, ascariasis, enterobiasis, opisthorchiasis, echinococcosis)
• Infectious diseases (scarlet fever, tuberculosis, mononucleosis, venereal diseases)
• Cancers
• Diseases of the hematopoietic system (leukemia, lymphoma, lymphogranulomatosis)
• Rheumatic diseases (rheumatoid arthritis, periarteritis nodosa, scleroderma)

Reasons for increased blood basophils

• chronic myelogenous leukemia
• decreased thyroid hormone levels hypothyroidism
• chickenpox
• food and drug allergies
• nephrosis
• hemolytic anemia
• condition after splenectomy
• Hodgkin's disease
• treatment with hormonal drugs (estrogens, drugs that reduce thyroid activity)
• ulcerative colitis

Reasons for increased blood monocytes

• Infections caused by viruses, fungi, parasites and protozoa.
• Recovery period after an acute inflammatory process.
• Specific diseases: tuberculosis, syphilis, sarcoidosis, nonspecific ulcerative colitis, brucellosis.

• Rheumatic diseases - systemic lupus erythematosus, rheumatoid arthritis, periarteritis nodosa.
• Diseases of the hematopoietic system: acute leukemia, myeloma, lymphogranulomatosis.
• Phosphorus poisoning, tetrachloroethane.

Monocytopenia

• aplastic anemia
• hairy cell leukemia
• purulent lesions (abscesses, phlegmons, osteomyelitis)
• childbirth
• after surgery
• taking steroid drugs (dexamethasone, prednisolone)

Lymphocytosis

• Viral infections: infectious mononucleosis, viral hepatitis, cytomegalovirus infection, herpes infection, rubella, SARS.
• Toxoplasmosis
• Blood system diseases: acute lymphocytic leukemia, chronic lymphocytic leukemia, lymphosarcoma, heavy chain disease - Franklin's disease;
• Poisoning with tetrachloroethane, lead, arsenic, carbon disulfide
• Use of drugs: levodopa, phenytoin, valproic acid, narcotic analgesics.
• Leukemia.

Lymphopenia

• Tuberculosis
• Lymphogranulomatosis
• Systemic lupus erythematosus
• Aplastic anemia
• Renal failure
• End-stage cancer
• AIDS
• Radiotherapy
• Chemotherapy
• Use of glucocorticoids

Leukocytosis

Leukocytosis can be:
neutrophilic, eosinophilic, monocytic, lymphocytic,
rarely due to an increase in another type of cell.

Causes of leukocytosis

- leukocytosis can be absolute and relative,
- relative or redistributive leukocytosis occurs as a result of vascular reactions with the expulsion of leukocytes from blood depots,
- digestive (especially after protein food),
- myogenic after muscle work or due to cramps,
- sympathetic-vegetative influences - hot and cold baths, emotional factor, pregnancy (mixed nature of leukocytosis)

Causes of absolute leukocytosis

• Absolute leukocytosis can be functional and organic

• **Functional leukocytosis** occurs as a result of stimulation of the leukopoietic function of hematopoietic organs due to the action of specific pathogens and inflammatory factors, is temporary

• Acute infectious processes (except typhoid fever, brucellosis, most viral infections)

• Inflammatory diseases (pneumonia, pleurisy, etc.)

• Purulent processes (sepsis, erysipelas, meningitis, etc.)

• The effect of various medications - corticosteroid drugs, interleukins, vaccines and serums.

• Endogenous intoxications - myocardial infarction, major burns, malignant tumors, uremia

• Exogenous intoxications - arsenic, nitrobenzene, carbon monoxide, etc.

• Exposure to ionizing radiation

• Significant blood loss (especially hemorrhages into closed cavities)

• Shock, postoperative conditions, epilepsy.

• **Organic leukocytosis** - acute and chronic hemoblastoses

Causes of leukopenia

▪ ***functional***

▪ Neuro-vegetative influences (predominance of the tone of the parasympathetic nervous system, fasting, asthenoneurotic syndrome, during deep sleep, in old and exhausted people)

▪ Bacterial infections (typhoid fever, brucellosis, prolonged septic endocarditis)

▪ Viral infections - influenza, measles, rubella, viral hepatitis,

▪ Splenomegaly

▪ Systemic lupus erythematosus

▪ ***organic***

▪ Agranulocytosis

▪ Hypo- and aplastic conditions

▪ Some hemoblastoses

▪ Exposure to ionizing radiation

Thrombocytosis

• removal of the spleen

• inflammatory processes (exacerbation of rheumatism, osteomyelitis, tuberculosis, abscess)

• various types of anemia (after blood loss, iron deficiency, hemolytic)

• after surgery

• cancer of various localization

• physical overwork

• erythremia

Thrombocytopenia

• congenital blood diseases (hemophilia)

• idiopathic autoimmune thrombocytopenic purpura

• drug-induced thrombocytopenia

• systemic lupus erythematosus
• infections (viral and bacterial infections, rickettsiosis, malaria, toxoplasmosis)
• aplastic anemia
• paroxysmal nocturnal hemoglobinuria
• autoimmune hemolytic anemia and thrombocytopenia
• DIC syndrome (disseminated intravascular coagulation)
• Blood transfusion
• In children born prematurely
• in hemolytic disease of the newborn
• heart failure
• renal vein thrombosis

Modern technologies of hematological analysis

Currently, hematological analyzers of various levels of complexity are used for counting and analyzing blood cells.

The advantage of modern technologies for counting and evaluating blood cells:
- high productivity (up to 100-120 samples per hour),
- small volume of blood for analysis (12-150 μl)
- analysis of a large array (tens of thousands) of cells
- determination with high accuracy and reproducibility of
20 or more parameters simultaneously
- graphical presentation of research results (histograms, scatograms).

Preparation and conduct of research on hematological analyzers

• When performing analysis on a hematological analyzer, it is preferable to use venous blood. Venous blood collection is best carried out using special disposable systems with EDTA - "MONOVET". This guarantees the absence of foreign impurities in the sample, and the presence of an anticoagulant in an optimal concentration prevents the formation of fibrin clots and platelet aggregation.

• When taking capillary blood, it is optimal to use EDTA tubes - "MICROVIT". Fine EDTA powder applied to the inner surface of the tube quickly dissolves in the blood and reliably blocks the processes of blood clotting and platelet activation.

• Tubes with evaporated EDTA solution should not be used. When the solution evaporates at the bottom of the tube, large EDTA crystals form, which dissolve very slowly in the blood. This can cause the formation of fibrin threads in the upper part of the blood sample.

• Whole blood has a high viscosity and is therefore difficult to mix. Before starting the measurement, whole blood should be mixed by gently turning and rotating the tube for at least 2 minutes. For this, it is better to use a special hematological shaker.

• When manually mixing whole blood, sharp shaking movements are not permissible, as they lead to mechanical lysis of erythrocytes.

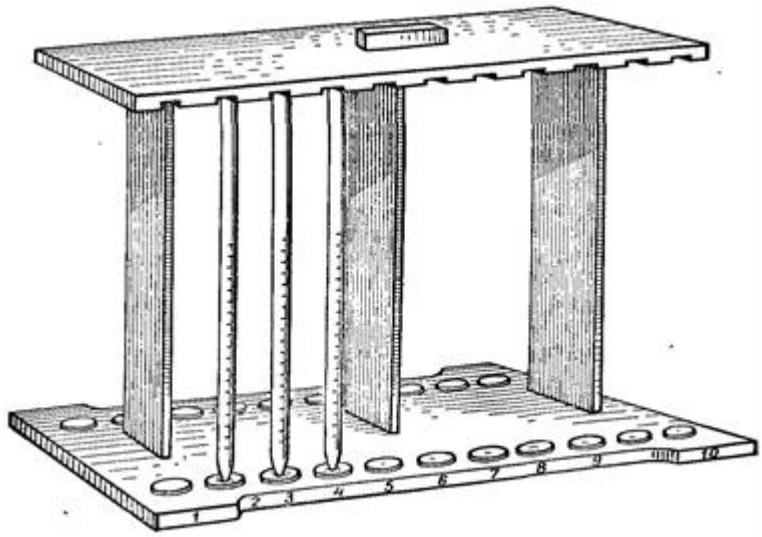
• To disinfect the fingertip before blood collection and to dry the tube tip, special lint-free wipes should be used. Remember that the use of cotton swabs and other fibrous materials of this kind leads to clogging of the cell counting sensor and hemoglobin chamber with fibers (even one fiber is enough for this!). As a result, the accuracy and reproducibility of hemoglobin concentration measurement drops sharply. Removing

foreign particles from the chamber requires an increased consumption of washing solution, and in some cases, even partial disassembly of the device.

Parameters determined:

WBC – Leukocytes
RBC – Red blood cells
Hgb – Hemoglobin, g/l
Hct – Hematocrit, %
MCV – Mean erythrocyte volume MCH – Mean hemoglobin content in erythrocytes
MCHC – Mean hemoglobin concentration in erythrocytes
RDW – Hemoglobin distribution index of erythrocytes
Plt – Platelets
MPV – Mean platelet volume
PDW – Hemoglobin distribution index of platelets
Pct – Thrombocrit
LY% – Lymphocytes, %
LY# – Lymphocytes, µl
MO% – Monocytes, %
MO# – Monocytes, µl
NE% – Neutrophils, %
NE# – Neutrophils, µl
EO% – Eosinophils, %
EO# – Eosinophils, µl
BA% – Basophils, %
BA# – Basophils, µl
RE% – Reticulocytes, %
RE# - Reticulocytes, µl
MRV* - Mean Reticulocyte Volume
IRF* - Reticulocyte Maturity Factor
HLR%* - Mature Reticulocytes, %
HLR#* - Mature Reticulocytes, µl
MSCV* - Sphericity
Methods for ESR determination

- Panchenkov micromethod
- Automated method



Pic.6. Panchenkov's apparatus

Clinical and diagnostic significance of ESR determination

• An increase in ESR is observed in various inflammatory processes, acute and chronic infections, myocardial infarction, tumors, after blood loss, surgical interventions. ESR increases during pregnancy, taking many steroid hormones (estrogens, glucocorticoids) and some drugs (for example, salicylates). An increase in ESR is observed in hypercholesterolemia.

• A particularly pronounced acceleration of ESR (60-80 mm/h) is characteristic of paraproteinemic hemoblastoses

(multiple myeloma, Waldenström's macroglobulinemia, acute plasmablastic leukemia, etc.) and symptomatic paraproteinemias, concomitant malignant neoplasms of loidosis, collagenoses.

Errors during ESR analysis can be associated with various factors

• At room temperature, ESR is determined no later than 2 hours after blood collection. In case of blood storage at +4°C, ESR is determined within no more than 6 hours, but before performing the reaction, the blood is warmed to room temperature.

• ESR analysis should be performed at 18-25°C. At higher temperatures, the ESR value increases, at low temperatures it slows down.

• Before performing the analysis, the blood is mixed well, which will ensure the best reproducibility of the results.

• In the absence of a sharp boundary between the erythrocyte column and plasma (regenerative anemias), a light “veil” of several millimeters is formed above the compact mass of erythrocytes, consisting of diluted erythrocytes (mainly reticulocytes).

In this case, the boundary of the compact layer is determined, and the erythrocyte veil is included in the plasma column.

• Glass capillary pipettes can be replaced with plastic ones (polypropylene, polycarbonate), however, they require verification and assessment of the degree of correlation of the obtained results with glass capillaries.

• Violation of the blood/citrate ratio (inaccurate dosage of citrate or blood), standing in the light, in the heat, for more than 4 hours with citrate
Iron deficiency anemia occurs in:
• 40-60% of women of childbearing age
• 40% in early childhood
• 1-3% of men
• 27-40% of men aged 80 and over
• Blood loss is practically the main cause of iron deficiency anemia. In 25% of women, daily iron loss exceeds 2-2.5 mg – the threshold for iron absorption in the intestine.

Pic.7. Biochemical blood test

Biochemical blood test is a comprehensive study of the patient's venous blood, which is carried out to assess the functioning of internal organs, identify deficiencies of vitamins, enzymes, macro- and microelements, as well as to diagnose metabolic pathologies. Blood biochemistry is more indicative than a general clinical analysis, the results of the analysis allow you to detect many diseases at an early stage. That is why this study is recommended to be carried out not only as prescribed by a doctor, but also for preventive purposes at least once a year. The results of a biochemical blood test cover many interrelated indicators and their interpretation should be handled by a doctor - self-medication is dangerous for your health!

How to prepare for the procedure?

• Blood sampling for biochemistry is always performed on an empty stomach, most often between 8 and 11 am. On the day of the procedure, non-carbonated water is allowed, and heavy food, carbonated drinks, strong coffee, tea and alcohol should be excluded from the diet the day before the procedure.
• In the last hour before donating blood, you should not smoke.

• Immediately before the procedure, try to avoid physical and emotional stress; for the last 10-20 minutes, it is better to just sit near the manipulation room.
• If the date of the biochemical blood test falls on the period of taking a course of medication or physiotherapy, you should consult a doctor - he may recommend postponing the study to another time or interrupting the course of treatment for several days.

Interpretation of the results of biochemical blood tests

New generation laboratory analyzers are able to provide the results of the study within two hours after blood sampling. As a rule, the patient receives the results within 2-3 days in the form of a printed or electronic table, which lists the studied indicators, their values, and reference (average) normal ranges. Different laboratories offer different amounts of data; this article will describe the most frequently studied blood parameters.

	Marking	Norm (women)	Norm (men)	Units of measurement
Albumin	ALB	< 14 years: 38–54 14–60 years: 35–50 > 60 years: 34–38		g/l
Glycated hemoglobin	Glycated hemoglobin HbA1c, A1c, glycohemoglobin, glycosylated hemoglobin	< 5.7		%
Total protein	Total protein TP, TProt, Serum	< 1 year: 47–72 1–4 years: 61–75 5–7 years: 52–78 8–15 years: 58–76 > 15 years: 64–83		g/l
C-reactive protein	CRP	< 0.5		g/l
Serum iron binding capacity	TIBC, IBC	45.3–77.1		μmol/L
Myoglobin	Myoglobin	12–76	19–92	μg/l
Transferrin	Tf	2.2–2.4	2–4	g/l
Ferritin	Ferritin	13–150	30–400	μg/l

Total protein characterizes the state of protein metabolism and reveals dysproteinemia (changes in the quantitative ratio of protein fractions in the blood serum). Reduced values may indicate malnutrition, liver disease, the consequences of burns, injuries and operations, and increased values may indicate an infectious disease, non-infectious hepatitis, autoimmune diseases, dehydration or may be caused by diarrhea and vomiting.

The albumin protein occupies up to 65% of the blood plasma volume, is produced by the liver and performs the most important function of transporting many biologically active substances. The reasons for a decrease in albumin concentration coincide with those for total protein. The value increases quite rarely, for example, with dehydration, hemoconcentration or due to taking anabolic steroids.

The iron-containing protein myoglobin is studied mainly for the purpose of early diagnosis of myocardial infarction. High myoglobin concentration may indicate myocardial infarction, heart failure, acute kidney injury, consequences of thermal burns, electric shock. Low myoglobin accompanies the course of rheumatoid arthritis and poliomyelitis.

The value of glycated or glycosylated hemoglobin is very important for patients with diabetes mellitus, and is also used for its diagnosis. Glycated hemoglobin gives an idea of the average level of glucose in the blood over a long period of time (1-2 months). If the concentration of this protein fraction does not exceed 5.7% of the total hemoglobin in the blood, then we can speak of a compensated state. Values in the range of 5.7 - 6.4% indicate the risk of developing diabetes mellitus, above 6.4% - about severe decompensated diabetes.

C-reactive protein acts as an indicator of the inflammatory process in the body. Exceeding the threshold of 0.5 g/l indicates acute inflammation or malignant neoplasm. This parameter is also important for assessing the effectiveness of antibacterial and anti-inflammatory therapy.

The studied values of transferrin, ferritin and iron-binding capacity of serum allow to diagnose pathology of iron metabolism in the blood. Transferrin is the main iron carrier, an increase in its concentration, as a rule, indicates the development of iron deficiency anemia, and a decrease - about infections, cirrhosis of the liver, anemia of other etiology or protein starvation. In iron deficiency anemia, ferritin, on the contrary, decreases, and its increase indicates inflammatory processes, liver disease or oncological pathology.

Lipids

	Designation	Norm (women)	Norm (men)	Units of measurement
Triglycerides	TRIG	< 15 years: 0.40–1.48 15–30 years: 0.4–1.63 30–55 years: 0.44–2.63 > 55 years: 0.62–2.71	< 15 years: 0.34–1.41 15–30 years: 0.45–2.81 30–55 years: 0.56–3.61 > 55 years: 0.65–3.29	mmol/l
Total cholesterol	CHOL	5.2		mmol/l
Cholesterol-HDL	Cholesterol-HDL HDL	1.03–1.55		mmol/L
LDL	LDL	0–3.3		mmol/L

cholesterol,	cholesterol, LDL-C		

Total cholesterol is used to detect primary and secondary disorders of lipid metabolism, assess the likelihood of atherosclerosis, and also to assess the effectiveness of treatment of atherogenic disorders of lipid metabolism. A decrease in the value is caused by cachexia, starvation, malabsorption, severe acute diseases, liver failure, hyperthyroidism, and an increase is caused by primary and secondary dyslipoproteinemia. The dangerous consequences of low cholesterol are psychophysiological disorders and reproductive dysfunction, and high cholesterol is diabetes mellitus and atherosclerosis. Biochemical blood test for triglycerides (products of carbohydrate metabolism in the liver) pursues the same tasks, the reasons for the increase and decrease in their concentration also coincide with total cholesterol. High and low density lipoprotein cholesterol (HDL-C and LDL-C, respectively) is examined and interpreted in combination with total cholesterol and triglycerides for a more accurate diagnosis. HDL-C is increased in primary biliary cirrhosis, hepatitis, alcoholism, or its increase may be due to genetics. In patients with atherosclerosis, decompensated diabetes mellitus, chronic kidney disease, cholestasis, the value of HDL-C is reduced. Low-density lipoproteins are involved in the processing and excretion of fats, a decrease in their concentration may indicate the development of chronic anemia, Raynaud's syndrome or myeloma, and an increase may indicate hypothyroidism, nephrotic syndrome, diabetes mellitus, porphyria, Cushing's syndrome, the risk of developing atherosclerosis.

	Designation	Norm (women)	Norm (men)	Units of measurement
Glucose	GLUC	3.3–5.5		mmol/l
Fructosamine	FRA	0–285		μmol/L

Glucose is the main source of energy for all cells and tissues of the human body and, in particular, its only source for the brain. The value of glucose in the results of biochemical analysis shows the level of sugar in the blood. If this value is increased, then there is a possible risk of developing diabetes mellitus, damage to the central nervous system, hormonal disorders. Glucose "falls" when tumors form in the pancreas, with liver and adrenal insufficiency, hypothyroidism, malnutrition or due to taking insulin. The value of fructosamine shows fluctuations in the level of glucose in the blood during the 2-3 weeks preceding the analysis. If its concentration exceeds 280–285 μmol/l, then the doctor considers the possibility of developing diabetes mellitus.

Inorganic substances and vitamins	Designation	Norm (women)	Norm (men)	Units of measurement
Vitamin B_{12}	B_{12}	208–963.5		pg/ml
Iron	Fe, IRON	< 2 years: 7–18 2–14 years: 9–22	< 2 years: 7–18 2–14 years: 9–22	μmol/l

		> 14 years: 9–30	> 14 years: 11–31	
Potassium	K	3.5–5		mmol/l
Calcium	Ca	2.25–2.5		mmol/l
Magnesium	Mg	0.75–1.25		mmol/l
Sodium	Na	136–145		mmol/l
Phosphorus	P	< 2 years: 1.45–2.16 2–12 years: 1.45–1.78 12–60 years: 0.87–1.45 > 60 years: 0.90–1.32	< 2 years: 1.45–2.16 2–12 years: 1.45–1.78 12–60 years: 0.87–1.45 > 60 years: 0.74–1.2	mmol/l
Chlorine	Cl	98–107		mmol/l

Vitamin B_{12} in the human body is involved, in particular, in the production of red blood cells. High levels of this vitamin may indicate liver disease, kidney disease or leukemia. Diseases of parasitic etiology, inflammatory processes in the gastrointestinal tract and adherence to a vegetarian (vegan) diet, on the contrary, lead to a decrease in the level of vitamin B_{12} in the blood.

In one of the previous paragraphs, it was mentioned that iron is involved in the process of oxygen transport. Its deficiency is usually explained by malnutrition or metabolic disorders, and its excess is due to functional disorders of the intestines.

Potassium is responsible for regulating water balance and normalizes heart rhythm. Potassium deficiency occurs as a result of malnutrition or malnutrition, vomiting, renal failure, Cushing's syndrome, osmotic diuresis, chronic kidney disease, and also accompanies long-term use of steroid drugs. Potassium increases with acute dehydration, major injuries and burns, chronic adrenal insufficiency, diabetic coma or due to taking potassium-sparing diuretics.

Calcium is involved in the formation of bone tissue, it is extremely important for the normal functioning of muscles, nerves, heart muscle and blood vessels. Low calcium values in the blood indicate vitamin D deficiency, functional kidney diseases, pancreatitis, impaired magnesium metabolism or hypoparathyroidism. An increase in calcium levels accompanies hyperparathyroidism or is a symptom of oncological pathology.

Magnesium performs the function of intracellular metabolism and transmission of impulses from nerve endings to muscles. Malnutrition, malabsorption, prolonged diarrhea, colitis, enterocolitis and dyspepsia reduce the concentration of magnesium in the blood. Its increase is caused by functional kidney disorders, hypothyroidism, lactic acidosis and neoplasms.

Along with magnesium, sodium is responsible for transmitting impulses to the muscles, which is also involved in calcium metabolism. The cause of low sodium levels may be hypothyroidism, Addison's disease, diabetes mellitus, kidney and gastrointestinal diseases, congestive heart failure, taking gentamicin, less often -

Parkhon syndrome or hypercalciuria. High sodium levels in biochemistry results indicate dehydration, salt overload, diabetes insipidus or kidney disease with oliguria. Normal functioning of the nervous and musculoskeletal systems is impossible without a sufficient amount of phosphorus in the body. The phosphorus content in the blood increases with hypoparathyroidism, excess vitamin D, rhabdomyolysis, bone diseases or an improper diet, less often - with acromegaly. On the other hand, hypovitaminosis D, hyperparathyroidism, kidney transplantation, intravenous glucose infusions, respiratory alkalosis cause a decrease in the concentration of phosphorus in the blood.

Chlorine performs the functions of maintaining the acid-base balance of the blood and osmotic pressure. The most obvious causes of a decrease in the level of chlorine are profuse sweating, vomiting, diarrhea, incorrect treatment with diuretics, less often the decrease is caused by nephrotic syndrome and hypokalemic metabolic syndrome. Excess chlorine in the blood can be a consequence of dehydration, edema, alkalosis and decompensation of cardiac activity.

Low molecular weight nitrogenous substances

Low molecular weight nitrogenous substances	Designation	Norm (women)	Norm (men)	Units of measurement
Creatinine	CREA	53–97	62–115	μmol/l
Uric acid	UA	Uric acid UA < 14 years: 120–320 > 14 years: 150–350	< 14 years: 120–320 > 14 years: 210–420	μmol/L
Urea	UREA	2.2–6.7	3.8–7.3	mmol/l

Urea and creatinine are examined in combination, their values show the functional state of the patient's kidneys, in particular, the degree of impaired filtration and excretory functions. High values indicate kidney problems, but can be explained by excessive physical exertion, a high-protein diet, prolonged fasting or thyroid diseases. Low urea values can be explained by a low-protein diet, pregnancy and liver diseases. The level of uric acid, as an auxiliary parameter, indicates the body's ability to remove waste products of nucleic acid and purine metabolism. It is of particular diagnostic interest for patients with gout. The main causes of increased uric acid are gout and alcoholism, less often - kidney and liver pathology. Low uric acid values in the results of biochemical blood tests are much less common and in most cases indicate improper or insufficient nutrition.

Pigments

Pigments	Designation	Norm (women)	Norm (men)	Units of measurement
Total bilirubin	BILT	3.4–17.1		μmol/l
Direct bilirubin	BILD, D-BIL	0–7.9		μmol/l
Indirect bilirubin	ID-BIL BILT - BILD	< 16,2		μmol/l

Enzymes

Enzymes	Designation	Norm (women)	Norm (men)	Units of measurement
Alanine aminotransferase	ALT	< 31	< 41	units/l
Amylase	AMY	28–100		units/l
Pancreatic amylase	AMY-P	0–50		units/l
Aspartate aminotransferase	AST	< 32	< 40	units/l
Gamma-glutamyltransferase	GGT	6–42	10–71	units/l
Creatine kinase	CK	0–25		units/l
Lactate dehydrogenase	LDH	250		units/l
Lipase	LIP	0–190		units/l
Alkaline phosphatase	ALP	0–240	0–270	units/l
Cholinesterase	CHE	5860–11800	5800–14600	units/l

The yellow pigment bilirubin begins to accumulate in the blood in diseases and hereditary pathologies of the liver and biliary tract, for example, in Gilbert's syndrome. Indirect bilirubin can also increase in some anemias and malaria.

The liver enzyme alanine aminotransferase is involved in amino acid metabolism. The indicator increases in myocardial infarction, acute hepatitis A and B, and other liver diseases.

The enzyme amylase is produced by the salivary glands and pancreas, and is responsible for the digestion of carbohydrates. Exceeding the norm by 3–5 times may indicate acute appendicitis, peritonitis, gastric ulcer and duodenal ulcer, cholecystitis. In acute pancreatitis or exacerbation of its chronic form, the value of amylase increases by 10–30 times. Increased pancreatic amylase levels allow for timely detection of complications of abdominal surgery and pancreatic diseases.

The concentration of the aspartate aminotransferase enzyme in human blood increases significantly in case of liver or heart muscle damage; due to alcohol abuse, the levels can double compared to normal.

High values of the gammaglutamyltransferase enzyme are observed in patients with acute hepatitis, extrahepatic and intrahepatic cholestasis, alcoholism, pancreatic and prostate cancer, and primary liver tumors.
An increase in the concentration of creatine kinase in the blood may indicate myocardial infarction, muscle damage of various genesis, and renal failure. Lactate dehydrogenase is increased in diseases of the cardiovascular system, liver and kidneys, as well as in pregnant women. High values of lipase are observed in patients with acute pancreatitis, intestinal infarction, biliary colic, wounds, fractures, breast cancer. Phosphorus metabolism in the body is directly related to the content of alkaline phosphatase - its increase accompanies acute viral and alcoholic hepatitis, cirrhosis of the liver, mononucleosis, liver cancer or metastases to it. Cholinesterase decreases in cirrhosis of the liver, liver failure, hepatitis, myocardial infarction. The value of cholinesterase is also indicative for patients taking muscle relaxants.

CYTOLOGICAL EXAMINATION

Pic.8. Cytological examination.

It is an auxiliary method of pathomorphological diagnostics and is based on the study and evaluation of cellular material obtained from a pathological focus by means of fine-needle puncture, scraping or impression from a pathologically altered surface. In this case, the obtained material contains a very small amount of tissue in the form of individual groups of cells. This allows for a qualitative analysis - malignant process or benign, and to approximately assess the type of tumor. The advantages of cytological examination are simplicity, low traumatism, speed and low cost. The disadvantages include low accuracy and specificity, as well as the impossibility (in most cases) of determining the most important biological properties of the tumor.
Cytological examination is used to evaluate discharge from the nipples, punctates of cystic and other fluid formations, as well as suspicious lymph nodes. In certain cases, cytological examination as a result of fine-needle biopsy can also be used to diagnose nodular formations in the mammary gland and soft tissues. However, establishing a final diagnosis and prescribing oncological treatment based on such a study is unacceptable.
The PAP test is the world standard for diagnosing precancerous diseases and cervical cancer in women. Cytological analysis (PAP test) is an examination of the cervical mucosa and cervical canal for the presence of atypical cells and other

pathological changes in the cervical epithelium. Cytological examination helps to assess the structure and correct functioning of cells. To make a diagnosis, the doctor takes a sample of cells (smear), which is then examined under a microscope using specific dyes and other auxiliary methods.

The PAP test is an important screening examination for early diagnosis of cervical cancer. It is safe, simple and painless, helps to detect precancerous conditions or the development of a cancerous tumor in the cervix, that is, it provides an opportunity to start treatment at an early stage and prevent the progression of the disease. This tool is expected to significantly reduce the incidence and mortality from cervical cancer. It is recommended to undergo regular preventive examinations at least once a year for all sexually active women, especially if they have been diagnosed with a high-risk human papillomavirus or if changes in the mucosa have been detected during colposcopy. Preparation. To obtain the most accurate result, it is necessary to fulfill a number of conditions before taking a PAP test. It is not recommended to conduct an examination during menstruation or in the presence of an inflammatory process. For 48 hours before taking a PAP smear, it is necessary to refrain from sexual contact, the use of tampons, the use of vaginal creams, suppositories and medications, douching and vaginal douching.

Bacteriological culture is a study conducted to identify microorganisms that are pathogens of a number of diseases. This type of diagnosis is highly informative: it allows you to accurately determine the type of bacteria and identify their sensitivity to certain antibiotics. The material used for the study is samples of fluids or secretions from the nose, eyes, genitals. The samples are placed in a nutrient medium for a period of 3 to 10 days, after which they are studied in a microbiological laboratory and the result is evaluated.

Such an analysis is performed by a doctor when an infection is suspected, to confirm the diagnosis, and to monitor the treatment process. It helps to identify a number of infectious diseases, the pathogens of which are: staphylococci, streptococci, yeast fungi (candida), enterococci, gram-positive and gram-negative microbes, as well as conditionally pathogenic microorganisms. Having at his disposal the results of the diagnosis, the doctor can identify pathology, clarify the diagnosis, and prescribe additional studies.

Indications for bacterial culture are the presence of signs of an infectious process, as well as contact of a healthy person with an infected infectious disease in the absence of symptoms.

The analysis is performed:

• To identify the cause of inflammation of the urinary system (bacterial culture of urine).
• In case of complicated infectious diseases and suspicion of bacteremia.
• In case of urogenital infections, for the diagnosis of infertility.
• In case of infection with an infectious agent in pregnant women.
• For the diagnosis of intestinal infections.
• In case of infections of ENT organs.
• In case of purulent-inflammatory eye diseases.

How to properly prepare and pass a bacterial culture

There are general rules that must be followed to obtain a reliable diagnostic result. A smear or scraping must be taken by specially trained medical personnel. The material for each analysis is collected separately, after which the biological fluid is placed in a nutrient medium for a clearly defined period. If colonies of bacteria of different types are detected in the culture, the analysis is repeated. If conditionally pathogenic and pathogenic microorganisms are detected, a test is performed for their sensitivity to certain antibiotics.

It is important to properly prepare for the bacterial culture. In order for the study to give an accurate result, you must stop taking antibiotics 14 days before the analysis, do not drink alcoholic beverages and medications containing ethanol. If a bacterial culture for microflora is required in women, special preparation is not required. Before visiting the laboratory, do not douche, use vaginal suppositories, and exclude sexual intercourse one day before the diagnosis. The analysis is not taken during menstruation and in the presence of blood discharge. In men, a smear is taken from the urethra. Sexual intercourse is stopped one day before the analysis. The material is collected no earlier than 2 hours after urination.

To perform a bacterial urine culture, it is necessary: to perform a hygienic toilet of the external genitalia, collect the liquid in a sterile container. Urine is collected on an empty stomach, in the morning immediately after sleep. The amount is 50-150 ml. The container must be delivered to the laboratory within 2 hours.

Fecal culture - the collection of material does not require special preparation. You cannot do an enema, take laxatives, use suppositories. A special sterile container is required. In order to correctly pass a sperm culture, you must stop sexual intercourse 2 days before the analysis, perform a toilet of the genitals, wash your hands with soap. When collecting a sample, contact with the walls inside the container is not allowed.

Decoding and meaning of bacterial culture

The results of diagnostics are necessary for diagnosis, as well as for the correct choice of drugs. Such analysis is especially important during long-term treatment without positive dynamics. For a repeated course, a drug is selected to which the identified pathogenic bacteria are sensitive.

Conducting bacterial culture is also necessary if the patient has an allergic reaction to antibiotics. It should be noted that the diagnosis cannot be made solely based on the results of bacterial culture. Thus, many conditionally pathogenic bacteria provoke the development of diseases with reduced immunity, in connection with which a comprehensive examination and individual selection of drug therapy are necessary.

A general or clinical urinalysis of the urine is a set of diagnostic tests aimed at studying the physicochemical and biochemical properties of the patient's urine, its microscopic examination. A general urine analysis is advisable when there is suspicion of kidney and urinary tract diseases of various etiologies, endocrine disorders, acidosis and alkalosis, dehydration, poisoning, gout, hemolytic anemia, hepatitis and a number of other pathologies, and is also prescribed for preventive purposes. The subjects of the study are organoleptic indicators (volume, color, odor,

transparency, foam formation), physicochemical characteristics (density, acidity), biochemical characteristics (protein, bilirubin), and the composition of the sediment.

Table of reference values for general urine analysis indicators

Indicator	Designation	Norm	Units of measurement
Organoleptic properties			
Color	COLOR	Straw yellow to yellow	
Scent		Specific, unobtrusive	
Foaminess		Virtually no foam when shaken	
Transparency	TURB	Absolute	
Physico-chemical properties			
Density	SG	1003–1030	g/l
Acidity	pH	5–7.5	
Biochemical composition			
Protein	PRO	0–0.033	g/l
Glucose	GLU	0–0.8	mmol/l
Bilirubin	BIL	0–8.5	μmol/l
Urobilinogen	URO, UBG	0–17	μmol/l
Ketone bodies	KET	0–0.5	mmol/l
Nitrites	NIT	absent	
Sediment microscopy			
Epithelium	SQEP, NSE	Males: 0–9 Females: 0–15	cells/μl
Mucus absent or traces	MUCS	absent or traces	
Red blood cells	RBC, BLD	0–11	cells/μl
White blood cells	WBC, LEU	Men: 0–16.5 Women: 0–27.5	cells/μl
Hemoglobin	HGB	Absent	
Casts (hyaline, granular, waxy)	HYAL, UNCC	Absent	
Salts		None	
Bacteria	BACT	Absent	
Parasites		None	
Color	Causes of color change		
Straw yellow color	norm		
Dark urine (the	Liver disease (hepatitis, cirrhosis, liver failure, gallstone		

color of strong black tea)	disease), massive destruction of red blood cells (after blood transfusion, a number of infections, malaria).
Dark yellow color	Dehydration due to vomiting, diarrhea, decreased fluid intake, heart failure.
Pale or colorless urine	Diabetes mellitus, diabetes insipidus, drinking, kidney pathology (impaired concentration function of the kidneys).
Red urine color	Consumption of pigmented fruits and vegetables (beets, carrots, blueberries, grapes).
Red urine color	A deep red color may indicate the presence of blood in the urine. This symptom can be observed with: urolithiasis, bladder cancer, kidney infarction, pyelonephritis, glomerulonephritis
Color of meat slops	Possible causes: acute glomerulonephritis, chronic glomerulonephritis, kidney stones, kidney infarction, tuberculosis of the kidneys and urinary tract, accelerated destruction of erythrocytes, use of drugs.).
Red-brown color.	Use of drugs: metronidazole, sulfonamide drugs, preparations from bearberry.

Causes of cloudy urine

• The presence of erythrocytes in it (urolithiasis, pyelonephritis, glomerulonephritis, bladder cancer, kidney, prostatitis)
• The presence of leukocytes (pyelonephritis, cystitis)
• High content of bacteria in the urine (pyelonephritis, cystitis)
• The presence of protein in the urine (pyelonephritis, glomerulonephritis, amyloidosis)
• A large amount of epithelium in the urine (pyelonephritis)
• Precipitation of salts (urates, phosphates, oxalates)

Deciphering the results of a general urine analysis

Color. It is customary to consider a straw-yellow color as normal, but even in a healthy person, depending on the diet and other factors, the shade can vary from colorless to amber. A clear change in color suggests pathology. A dark, beer color, up to brown and brown, indicates an increase in bilirubin or urobilinogen. If it looks like milk, there are increased leukocytes; black urine indicates the presence of hemoglobin or myoglobin. Red color is a dangerous sign, hinting at the excretion of blood in the urine; in rare cases, bluish-green shades are observed, which are explained by the processes of putrefaction in the intestines and the subsequent release of special coloring substances into the blood.

Smell. Ammonia after urination smells like bacterial infections and inflammatory processes in the urinary system; rotten fruit smells like an increase in the concentration of ketone bodies, which is usually a symptom of diabetes; diabetes can also “smell” like acetone.

Transparency. Turbidity of urine is caused by the deposition of salts, crystals, white and red blood cells, the presence of mucus and pus. Pronounced filamentous and flake-like compounds often accompany pyelonephritis and lower urinary tract

infections. But urine collected for analysis often becomes cloudy due to the laboratory's failure to observe the storage conditions of the sample.

Foaminess. If a lot of persistent foam is formed when shaking, this suggests to the specialist that jaundice is likely to occur or that the protein content is high. Other explanations may include the patient's poor psycho-emotional state, concussion, impaired blood circulation in the brain, advanced diabetes mellitus, heart failure, and a number of endocrine disorders.

Relative density. Specific gravity characterizes the ability of the kidneys to concentrate and dilute urine. An indicator beyond the lower limits of reference values indicates renal failure, polyuria, tubular pathology, or diabetes insipidus of various etiologies. Increased relative density values often indicate the development of glomerulonephritis, nephrotic syndrome, diabetes mellitus, dehydration, or are a consequence of intravenous administration of certain drugs and radiocontrast agents.

Acidity. In a healthy person, the urine reaction is slightly acidic, it shifts to the alkaline side (pH > 7) when consuming a large amount of plant and dairy products, and to the acidic side (pH < 5) when consuming animal products. Pathological acidification of urine is also caused by hypokalemia, diabetes mellitus, gout, and alkalization is caused by kidney and urinary tract diseases of an inflammatory or infectious nature, diarrhea, vomiting.

Proteins. The presence of protein in urine samples - proteinuria - can be a consequence of physical and emotional stress, a symptom of heart failure, arterial hypertension, increased body temperature, gestosis in pregnant women, nephroptosis, injuries. The activity of kidney filters can be impaired due to prolonged standing, so sometimes protein penetrates from the blood into the urine in hairdressers, salespeople, military personnel and people of other professions with sedentary work. Renal causes of proteinuria include tubular and glomerular damage, nephrosclerosis. Neoplasms can also make this test point positive.

Glucose. There should be no sugar in the urine. If the glucose value in the results of about 0.1 mmol/l may be a consequence of an excess of sweets in the diet, then values from 0.9 mmol/l and above clearly indicate a high probability of diabetes mellitus. Other relatively common causes of glycosuria are pancreatitis, Cushing's syndrome, Fanconi syndrome and pregnancy.

Ketone bodies. The appearance of ketone bodies in the tests of a patient with diabetes mellitus indicates the progress of the disease. In patients without diabetes, ketone bodies are detected during fasting, due to a sharp decrease in carbohydrates in the diet or prolonged fever.

Bilirubin. Determination of the amount of bilirubin in the urine becomes possible in case of damage to the liver parenchyma, impaired bile outflow, cirrhosis of the liver, viral hepatitis and metastasis of neoplasms to the liver.

Urobilinogen. Traces of urobilinogen in the urine may indicate blood diseases (hemolytic and pernicious anemia, hemolysis, polycythemia, a consequence of large hematomas), diseases of the gastrointestinal tract (inflammatory and obstructive diseases), liver diseases (viral hepatitis, chronic hepatitis, cirrhosis, secondary failure, neoplasms), disorders of the cardiovascular system (myocardial infarction, heart and

circulatory failure) or intoxication of the body with alcohol, infection or organic compounds.

Nitrites. Normally, nitrites are absent in the urine, their presence indicates urinary tract infection.

Erythrocytes. The correct interpretation of erythrocyturia requires taking into account the anamnesis and the results of a blood test, because there are many reasons for an increase in erythrocytes. The increase in concentration may have a physiological explanation and be temporary (long standing, exhausting walks and physical exertion), may accompany the intake of medications. If the causes of erythrocyturia are nevertheless pathological, then the specialist may suspect hypertension, diathesis, glomerulonephritis, urolithiasis, pyelonephritis, neoplasms, systemic lupus erythematosus, vasculitis, infective endocarditis, heart failure, injury or renal infarction.

Leukocytes. The level of leukocytes in the urine increases in almost all diseases of the kidneys and genitourinary system: all forms of pyelonephritis, glomerulonephritis, cystitis, urethritis, prostatitis, urolithiasis, lupus nephritis, etc. Another explanation may be fever.

Hemoglobin. Hemoglobin accumulates in the urine in parallel with erythrocyturia, with myositis, massive damage to muscle tissue, thrombus formation in muscle vessels, myocardial infarction, hemolytic anemia, burns, poisoning with mushrooms and phenol.

Epithelium. Elements of squamous, transitional and renal epithelium are distinguished. The appearance or increase in the number of squamous epithelial cells is observed with urinary tract infection, transitional epithelium - with cystitis, pyelonephritis and urolithiasis, renal epithelium - with glomerulonephritis, pyelonephritis, poisoning with heavy metal salts, pathology of renal blood circulation.

Cylinders. The detection of hyaline cylinders in the urine indicates kidney pathology, heart failure or overheating of the body (fever, heat stroke, sunstroke). In some cases, they are detected after excessive physical exertion, taking diuretics and exacerbations of arterial hypertension. Granular cylinders are excreted in the urine in glomerulonephritis, pyelonephritis, diabetic nephropathy, viral diseases, fever and lead intoxication. An increase in waxy cylinders indicates amyloidosis, renal failure or nephrotic syndrome.

Salts. Almost absent in the urine of a healthy person, their appearance hints at a violation of mineral metabolism, the development of urolithiasis, nephrolithiasis, dehydration of the body, chronic renal failure.

Mucus. The content of mucus in the sample is most often explained by a banal violation of the rules for collecting urine. But mucus is also actively excreted in the urine during inflammatory processes.

Bacteria, fungi, parasites. Their appearance in the urine is explained by the corresponding disease of the urinary tract.

Urine density

Urine density norms	
Newborns (age up to 10 days)	1.008-1.018
Children aged 2-3 years	1.010-1.017
Children aged 4-12 years	1.012-1.020
Children over 12 years of age and adults	1.010-1.022
Causes of increased urine density (>1.030 g/l)	Causes of decreased urine density (less than 1.010 g/l)
Diabetes mellitus; Glomerulonephritis, nephrotic syndrome; Use of high doses of drugs excreted in the urine (antibiotics, diuretics); Low fluid intake Excessive fluid loss (vomiting, diarrhea, profuse sweating) Preeclampsia Infection in the kidneys and urinary tract (pyelonephritis)	Diabetes insipidus; Kidney failure; Use of certain types of diuretics; Heavy drinking.

Causes of decreased urine acidity (pH >7)

Disturbances in the acid-base balance of the blood (respiratory or metabolic alkalosis)
Chronic renal failure
Increased levels of parathyroid hormone (parathormone)
Prolonged vomiting
Some types of genitourinary tract infections (ureaplasmosis)
Use of medications - nicotinamide, adrenaline
Cancer of the kidneys, bladder

Causes of increased urine acidity (pH <4)

Disturbances in the acid-base balance of the blood (respiratory or metabolic acidosis)
Dehydration (except for the cause of vomiting)
Starvation
Diabetes mellitus
High fever
Use of drugs: aspirin, methionine, diacarb

Albuminuria

Albuminuria of non-renal origin

Inflammation in the ureters, bladder and urethra.

Sometimes protein in the urine appears in healthy people after heavy physical exertion, long walking, cold shower, profuse sweating.

In physically poorly developed children 7-16 years old and pregnant women. with allergic reactions, leukemia, epilepsy, heart failure.

Pathological albuminuria.

It is always of renal origin and indicates kidney disease.

Albuminuria 3-5% is characteristic of acute glomerulonephritis, 0.5-1% - for chronic pyelonephritis and glomerulonephritis, with nephrosis (syphilitic, nephropathy of pregnant women) the amount of protein in the urine reaches high figures (more than 3%).

Ketone bodies are acetone, acetoacetic acid and oxybutyric acid

Causes of ketone bodies in urine

• Diabetes mellitus
• Alcohol intoxication
• Acute pancreatitis
• Prolonged fasting
• Predominance of protein and fatty foods in the diet
• After injuries affecting the central nervous system
• Increased levels of thyroid hormones (thyrotoxicosis)
• Itsenko-Cushing's disease

Bilirubin in urine

• **Causes of bilirubin in urine**:
• Hepatitis
• Cirrhosis of the liver
• Liver failure
• Gallstone disease
• von Willebrand's disease
• Massive destruction of red blood cells (malaria, toxic hemolysis, hemolytic disease, sickle cell anemia)

Causes of urobilinogen in urine

• Massive destruction of red blood cells (hemolytic anemia, blood transfusion, various infections, sepsis, use of certain medications)
• Intestinal inflammation (enterocolitis, colitis, ileitis)
• Liver failure, as a result of hepatitis, cirrhosis of the liver.

Reasons for the presence of hemoglobin in the urine

• Hemolytic disease
• Malaria
• Blood transfusion
• Major damage to muscle tissue (crash syndrome, contusion with massive hematoma)
• Major myocardial infarction
• Burns
• Poisoning by mushrooms, phenol, sulfonamide drugs

Erythrocytes in the urine

• appear with traumatic kidney damage (rupture, contusion, laceration),
• with kidney cancer,
• with acute nephritis
(glomerulonephritis, pyelonephritis)
• with urethritis, cystitis, bleeding in the urethra or ureters, kidney stones.

Causes of leukocytes in urine

• Kidney disease: pyelonephritis (chronic or acute), kidney tuberculosis, urolithiasis, kidney cancer.
• Ureteral damage: urolithiasis, infectious inflammation of the ureter
• Bladder damage: cystitis, bladder cancer.
• Prostate damage: prostatitis, prostate cancer.
• Urethra damage: urethritis, urolithiasis.
• Infections of the external genitalia or non-compliance with hygiene rules. In some cases, the presence of leukocytes in the urine may be associated with non-compliance with hygiene rules during urine collection or inflammation of the external genitalia (vulvovaginitis).

Casts in urine

• Casts are cylindrical bodies that form in the kidney tissue (in the renal tubules) with serious pathology.
• Casts can be of different composition and include: erythrocytes, exfoliated renal tubular cells, protein. In appearance they are: granular (predominantly erythrocytes and renal tubular cells), hyaline (predominantly renal tubular cells and protein), erythrocytic (the basis of such casts is erythrocytes).

Biochemical analysis of urine

• amylase (10-1240 units),
• glucose (0.03-0.05 g/l),
• total protein (up to 0.033 g/l),
• potassium (38.4-81.8 mmol/day),
• sodium (100-260 mmol/day),
• phosphorus (0.4-1.3 g/day),
• creatinine (in women - 0.48-1.44 g/l, in men - 0.64-1.6 g/l),
• magnesium (3.0-4.25 mmol/day),
• microalbumin (up to 3.0-4.25 mmol/day), • urea (from 333 to 587 mmol/day),
• uric acid (0.4-1 g/day).

Diastasis in urine

The norm of amylase (diastase) concentration in urine is 1-17 U/h.

Urine analysis according to Nechiporenko

• The number of leukocytes, erythrocytes and cylinders in 1 ml of urine is determined using a counting chamber.
• This is a study of the middle part of the urine stream, which is performed if a latent inflammatory process in the genitourinary system is suspected

Preparation for collecting urine for analysis

On the eve of collecting urine for analysis, it is not recommended to:
• drink more or less fluid than usual,
• take antibiotics or uroseptics,
• eat foods that cause urine staining (beets, blueberries, carrots, rhubarb, asparagus and others).

Urine analysis according to Nechiporenko

Normal indicators in men:
• leukocytes - up to 2000, • erythrocytes - up to 1000,

• cylinders - up to 20.
Normal indicators in women:
• leukocytes - up to 4000, • erythrocytes - up to 1000,
• cylinders - up to 20.

Urine analysis according to Ambourger

• The Ambourger method refers to methods for quantitative determination of formed elements in urine. In this case, the number of formed elements excreted in urine in 1 minute is determined.
• When studying with this method, the patient limits fluid intake during the day and excludes it at night. Urine is collected for 3 hours. In the morning, the patient empties the bladder (this urine is discarded), notes the time and collects urine for examination exactly 3 hours later.
• Normally, the number of leukocytes in the minute volume of urine is 2000, erythrocytes – 1000. Sometimes in the literature you can find other normal figures: leukocytes in the minute volume of urine – 2500, erythrocytes – 2000.

Yakovsky-Addis method

• To calculate the daily amount of formed elements according to the Yakovsky-Addis method, fluid intake is limited during the examination period: the patient should not drink at night and drink less during the day. At the same time, the relative density of urine (1020-1025) and its pH (5.5) are standardized, which is very important for this analysis.
• Urine is collected for 10–12 hours. The patient urinates before going to bed (this portion of urine is poured out), notes the time and urinates into a container after 1012 hours. This portion of urine is delivered to the laboratory for examination. If it is impossible to hold back urination for 10-12 hours, the patient urinates into a prepared container in several doses and notes the time of the last urination.
• The Yakovsky-Addis number for normal urine is
erythrocytes up to 1,000,000, leukocytes up to 2,000,000, cylinders up to 20,000.

Zimnitsky test

• Daily diuresis is normally 800-1600 ml.
• In a healthy person, the amount of urine excreted during the day exceeds the amount excreted at night.
• The relative density of urine varies no more than 1.009-1.028.

COPROGRAM

A coprogram or general stool analysis is a laboratory study of human feces in order to study its physical, chemical characteristics, composition, types of inclusions and further diagnostics of the gastrointestinal tract.

Preparation for stool analysis

1. 72 hours before the scheduled time of sample collection, stop taking antibacterial drugs, laxatives, corticosteroids, do not use rectal suppositories, enemas and ointments. It is advisable to consult a doctor about the need to stop the course of certain drugs.

2. 48 hours before the diet, exclude foods containing dyes (tomatoes, beets, blueberries, etc.), alcohol, dairy products, products that cause fermentation. Eat fatty, spicy and pickled dishes in moderation.
3. It is not recommended to do a coprogram during menstruation, as well as earlier than a week after contrast radiography.
4. Doctors recommend taking a stool sample for research in the morning on an empty stomach, without using an enema, laxative or other methods of stimulating peristalsis. It is better to deliver the container to the laboratory on the same day, the sooner the better. Storing a stool sample in the refrigerator is not recommended, as this may distort the results.
5. Water, urine, any other foreign liquids and chemicals should not get into the stool sample. It is recommended to urinate, then thoroughly rinse the perineum and genitals, and dry with a clean towel.
6. Defecation should not be carried out in the toilet bowl to avoid contact with water, urine or chemicals. Defecate in a clean container or on a surface that does not absorb moisture: in a pot, vessel, on oilcloth, a sheet of polyethylene, a special plastic container, etc.
7. A stool sample is taken with a special spoon, which is usually included in the package of a disposable sterile container from a pharmacy. A stool sample weighing 1–2 g should fill the container approximately one third of its volume. It is not allowed to transport a stool sample in matchboxes or other household containers not intended for this purpose.
8. When preparing for a stool test for occult blood, you should exclude from your diet foods with a high content of iron, bromine and iodine (apples, sweet peppers, beans, almonds, peanuts, seaweed, etc.), meat and fish products, all green and red plant products 72 hours before taking the sample.
9. For better tracking of dynamics, it is recommended to perform a coprogram in one laboratory.

Table of reference (normal) values for general stool analysis				
Indicator	Breastfed infants	Formula-fed infants	Children	Adults
Macroscopic characteristics				
Amount	40–50 g/day	30–40 g/day	100–250 g/day	10–400 g/day
Consistency	Viscous, mushy	Putty-like	Formed	Formed
Color	Color Yellow, with shades from golden to green	Light brown, orange	Brown to dark brown	Brown to dark brown
Smell	Sour, not very sharp, milky	Sour, pronounced	Fecal, not sharp	Fecal, not sharp
Mucus	Small amount of clear mucus acceptable	Small amount of clear mucus acceptable	Not detected	Not detected

Blood	Not detected	Not detected	Not detected	Not detected
Manure	Not detected	Not detected	Not detected	Not detected
Parasites	Not detected	Not detected	Not detected	Not detected
Undigested food	Not detected	Not detected	Small to moderate amounts of indigestible plant fiber allowed	Small to moderate amounts of indigestible plant fiber allowed
Chemical parameters				
Acidity, pH	4.8–5.8	6.8–7.5	7.0–7.5	7.0–7.5
Bilirubin	Up to three months, small amount permissible	Up to three months, small amount permissible	Not detected	Not detected
Stercobilin	Detected	Detected	Detected	75–350 mg/day
Soluble protein	Not detected	Not detected	Not detected	Not detected
Microscopic characteristics				
Ammonia	Not detected	Not detected	Up to 20–40 mmol/kg	Up to 20–40 mmol/kg
Starch	Not detected	Not detected	Not detected	Not detected
Neutral fats	Individual drops are permissible..	Small amounts are permissible.	Not detected.	Not detected.
Fatty acids	Small amount of crystals are allowed	Small amount of crystals are allowed	Not detected	Not detected
Soap	Small amount allowed up to one year	Small amount allowed up to one year	Not detected	Not detected
Digestible fiber	Not detected	Not detected	Not detected	Not detected
Muscle and connective tissue fibers	Not detected	Not detected	Small amounts may occur	Small amounts may occur
Erythrocytes	Not detected	Not detected	Not detected	Not detected
Leukocytes	Not detected or isolated	Not detected or isolated	Not detected or isolated	Not detected or isolated
Yeast-like fungi	Not detected	Not detected	Not detected	Not detected
Iodophilic bacteria	Not detected	Not detected	Not detected	Not detected
Epithelial	Not detected	Not detected	Not detected	Not detected or

cells	or isolated	or isolated	or isolated	isolated

Deciphering the results of a general stool analysis

The volume of feces excreted per day directly depends on the amount of food consumed and the diet. A large number of plant products in the diet increases the volume of excrement, protein products - reduces it. Deviation of the daily volume from the reference values, which has become regular, may indicate pathology: a constant increase - about enterocolitis, pancreatitis, cholecystitis, dyspepsia of various etiologies, increased intestinal motility or IBS, a constant decrease - about constipation or malnutrition.

The norm of stool consistency in children (after weaning) and adults is a formed cylindrical stool, which consists of approximately ¾ of water. Breastfed infants normally have mushy feces, and formula-fed babies - putty-like. Gallstone disease, cholecystitis and pancreatitis cause a putty-like consistency. Dysentery, salmonellosis, dyspepsia and enterocolitis cause foamy stool. Hard stool is a consequence of constipation, spasm of the intestinal walls, stenosis of the colon. There are many possible causes of loose stools, most often it is diarrhea, IBS or increased intestinal motility.

The pigment stercobilin gives the feces of an adult a characteristic brown color. In infants, the stool is lighter, towards light yellow, golden and green shades. In formula-fed infants, on the contrary, the stool is usually darker: from dark yellow to brown. Most often, the color of an adult's feces changes due to the peculiarities of the diet and after taking certain medications. If the rules for preparing for a stool analysis were followed, then what can the color change indicate: black - internal bleeding, varicose veins of the esophagus, peptic ulcer or stomach cancer; dark brown – recurrent constipation, excess protein in the diet, problems with digesting protein foods, colitis, dyspepsia; light brown – excess plant foods, IBS, increased intestinal motility; reddish brown – ulcerative colitis; light yellow – pancreatitis; grayish or almost white – hepatitis, cirrhosis of the liver, obstruction of the bile ducts.

A noticeable decrease in stercobilin in the results of the stool analysis, up to its absence, indicates functional problems with the liver, cholelithiasis, blockage of the bile ducts. If the indicator exceeds the norm, there is a suspicion of hemolytic anemia and excessive bile production.

A positive reaction to protein in the coprogram usually indicates pathology of the duodenum or stomach, dyspepsia, gastritis, enterocolitis, hemorrhoids.

Even the minimum concentration of ammonia in the feces of infants is considered a deviation from the norm. For adults, a concentration of about 20-40 mmol/kg is allowed. Increased ammonia content accompanies impaired fermentation and digestion of protein foods. The indicator also increases against the background of colitis and putrefactive dyspepsia.

Starch in a healthy body is completely broken down in the gastrointestinal tract and should not be "at the exit". Traces of intracellular starch in feces may appear with hyposecretion of gastric juice, putrefaction and fermentation processes. Extracellular starch, a product of the decay of plant cells, is not digested in the event

of insufficient production of the amylase enzyme by the body or due to an abnormally high speed of food movement through the gastrointestinal tract.

Neutral fats (triglycerides) and soap in a stool sample may be normal only for children under 1 year of age. For older children and adults, failure to digest fats is a sign of a functional disorder of the pancreas, liver or gallbladder. Fatty acids are detected in the results of stool analysis when the absorption function of the intestinal walls is impaired and with increased intestinal motility. Another reason for incomplete digestion of fats may be a banal excess of fatty foods in the diet or taking fat-containing medications.

Indigestible fiber may be present in the coprogram, it is not for nothing that it was called that. But the presence of digestible fiber in the analyzes at best indicates an excess of raw vegetables and fruits in the diet, in less pleasant situations - a violation of the secretory function of the stomach, the bile secretion process, accelerated evacuation of feces from the intestine.

In a healthy body, protein food (meat, fish) is completely digested. One of the manifestations of this process is the appearance of muscle fibers and connective tissue elements in the feces. The reason for this may be insufficient production of enzymes by the pancreas and a decrease in stomach acidity.

A positive reaction to erythrocytes when deciphering the feces analysis usually indicates hemorrhoids, cracks and ulcers in various parts of the intestine, polyps. The presence of leukocytes clearly indicates the course of the inflammatory process in one or more parts of the intestine. In the case of intestinal tumor disintegration, both erythrocytes and leukocytes are detected in the feces.

Yeast-like fungi multiply against the background of dysbacteriosis caused by taking antibiotics and/or corticosteroids.

Iodophilic bacteria got their name because of their property of changing color under the influence of iodine-containing solutions, for example, Lugol's solution.

Pathogenic cocci and rods are detected in the results of stool analysis in dysbacteriosis, active fermentation processes in the stomach, against the background of an excess of carbohydrates in the diet, insufficient production of pancreatic enzymes.

The presence of crystals in feces, depending on their chemical composition, may indicate putrefaction processes, bleeding from the intestinal walls, an allergic reaction, helminthic invasion.

The inclusion of squamous epithelial cells in feces has no diagnostic value, cylindrical epithelium indicates the course of acute or chronic colitis.

IMMUNOGRAM

Immunogram is a diagnostic method aimed at assessing the state of the human immune system. This is a laboratory study that allows you to establish the main indicators of the immune system, determine the level of the body's ability to resist various infections. Immunogram is a comprehensive study that includes laboratory analysis of all components that are of greatest importance for immunity.

Types of immunogram

1. Study of immune status with complement components.

Monoclonal antibodies on 7 cell subpopulations, phagocytosis, circulating immune complexes, immunoglobulins of classes IgM, IgG, IgA, complement components C3, C4.

2. Immunogram with sensitivity to immunomodulators.

After receiving the results of a comprehensive immunological study, patients can see an expanded immunogram as a whole, but only a specialist should be engaged in decoding the immunogram. For the average person, the numbers will remain numbers and will not mean anything.

When is it necessary to donate blood for an immunogram?

As a rule, a comprehensive immunological study is prescribed for both children and adults when an assessment of the immunological status is necessary to:

• check the state of the immune system;
• identify disorders in the function of the immune system;
• diagnose immunodeficiency states;
• confirm / refute the presence of a lymphoproliferative disease in the patient;
• determine the possibility of drug treatment and exclude complications associated with taking medications, etc.

Symptoms for which an immunogram may be prescribed:

• frequent manifestations of pain, aches, weakness in the body;
• inflammatory and fungal skin lesions;
• pronounced weight loss without any visible prerequisites;
• prolonged treatment of inflammatory and infectious diseases;
• enlarged cervical lymph nodes;
• rapid fatigue;
• temperature that lasts for 14 days or more (provided that other diagnostic methods do not reveal problems);
• frequent infections and skin rashes, etc.

Indications for immunogram:

• frequent incidence of infectious and inflammatory diseases (especially frequent bronchitis, otitis, tonsillitis, sinusitis) - more often than 4 times in 12 months;
• allergic diseases;
• long-term antibiotic therapy did not give the desired result;
• chronic infections (HIV, papillomavirus, herpes, viral hepatitis);
• skin diseases (including persistent fungal and pustular lesions);
• blood pathologies;
• medical problems from the group of autoimmune diseases;
• pathological conditions of the endocrine system (including diabetes mellitus);
• various types of immunodeficiencies.

Also, donating blood for an immunogram may be necessary for some types of cancer (especially at the stage of antitumor therapy) and patients who have undergone radiation.

Despite the important role of immunity in the treatment of sexually transmitted infections, they are not a direct indication for an immunogram.

Contraindications

The main contraindication to conducting a blood test for immunology is the acute period of infectious and inflammatory diseases (especially with fever). Also, an immunogram is not performed on women during menstruation and during normal (NOT pathological) pregnancy. Pregnant women may be prescribed a determination of immune status if there is a history of miscarriage (especially if a risk assessment was not carried out during planning), as well as in cases where there is suspicion of a violation of the mother's immunological tolerance to the fetus.

What does a blood test for immunology show?

An immunogram shows the state of cellular and humoral immunity, helps the doctor assess the patient's immunological status to prescribe the correct therapy. In essence, an immunogram is a complex analysis.

Unlike a general blood test, which counts the number of lymphocytes and monocytes, which are the basic cells of the immune system, when conducting an immunogram, these cells reveal all their features to specialists. This, in turn, allows you to detect immune disorders: to establish the presence of immunodeficiency states, lymphoproliferative diseases and other immunopathological processes.

Also, by analyzing the immunogram in dynamics, in comparison with clinical dynamics, the generalization and severity of the pathological process are assessed, its further course and development are predicted. Based on information about immunity, the doctor can make adjustments to the treatment and assess its effectiveness.

Features of biomaterial collection:

• material for immunological research – venous blood;

• for blood collection, special closed vacuum systems are used, which consist of a sterile double-sided needle with a safety valve for collecting liquid biomaterials, a disposable handle and sterile vacuum tubes – vacutainer (thanks to this, the procedure for taking biological material is painless and has an increased level of infectious safety);

• when donating blood for the study of humoral immunity indicators, a vacutainer with a special filler is used (vacuum tubes with a purple lid).

Preparation

In order for the immunogram result to be reliable and you to be sure that it fully reflects the state of your immune system, you should prepare for the analysis. Remember:

• any physical exertion should be excluded;

• on the eve of blood donation, you should not consume foods and/or drinks with a high fat and alcoholic content;

• in the morning before taking the test, you should give up your usual coffee, juice, tea, sweet drinks with gas, if you really want to drink, you can drink water;

• the test to determine the immune status is given strictly on an empty stomach from 8 to 10 am;

• do not smoke 2-3 hours before taking blood for the test;

• in a few weeks you need to stop taking antibiotics, hormones, etc. (their cancellation, temporary exclusion from the course of treatment must be discussed

with a doctor, there are conditions in which, on the recommendation of a doctor, treatment can and should be continued).

Also, the informativeness of the test can be affected by: climate change, weather, season, age, peculiarities of the nervous system, exacerbation of chronic diseases, nature of nutrition, taking pharmacological drugs (in particular, hormonal and antibacterial drugs).

ONCOMARKERS

Oncomarkers are chemical compounds and specific proteins, the concentration of which in the blood increases significantly in the presence of cancer. This informative diagnostic tool allows you to detect oncology in the early stages. The number of deaths from cancer, unfortunately, outweighs the cure rate. However, if you start treatment at the first stage, the chances of recovery are 90–92%, while at the fourth stage - no more than 10–13%.

Types of oncomarkers: what the analysis will show

Modern medicine in clinical practice uses approximately 35 tumor markers focused on various pathologies. This allows you to diagnose and monitor the course of a large number of oncopathologies.

In a modern clinic, you can conveniently and quickly perform tests for many types of tumor markers, for example:

- pancreatic cancer marker CA 19-9;
- ovarian cancer tumor marker CA 125;
- breast cancer marker CA-15-3;
- carcinoembryonic antigen CEA;
- squamous cell carcinoma antigen SCC;
- bladder cancer tumor marker;
- prostate cancer marker PSA (general tumor marker);
- gastrointestinal tumor marker CA 242;
- studies on other tumor markers.

Also in medicine, tests are used to detect the bladder cancer marker (UBC), hCG (reproductive system), AFP (usually for liver cancer), B-2-MG (lymphoma, leukemia, myeloma).

The same indicator may indicate different forms of cancer, and in some cases several markers indicate one oncopathology. When predicting the risk of oncology, it is sometimes necessary to compare the values of several oncomarkers. For example, to calculate the ROMA index, the ovarian tumor marker CA 125 and the tumor marker HE 4 are required. It is also worth understanding that an increase in the level of tumor markers in the blood is not yet a diagnosis. Many natural processes are also accompanied by an increase in the level of biomarkers. For example, CA 125 indicates ovarian cancer, but is the norm in the first trimester of pregnancy. And deviations from the normal values of the CEA tumor marker are characteristic of autoimmune or inflammatory diseases. Injuries and hormonal disruptions can also affect the level of biomarkers in the blood. Therefore, positive tests for tumor markers, the result of a blood test are a good reason to be wary and take a more

serious approach to the examination using additional laboratory and instrumental methods.

PCR - diagnostics

Polymerase chain reaction (PCR, polymerase chain reaction method, PCR) is one of the most modern, sensitive and accurate methods for diagnosing diseases. Polymerase chain reaction is carried out using special enzymes that copy RNA and DNA fragments of pathogens contained in samples of biological material many times.

Advantages of PCR

1. Direct determination of the presence of pathogens (detects nucleic acids of the pathogen).
2. High level of specificity (due to the peculiarity of the method: in the material being examined, a DNA fragment typical only for a certain pathogen is detected).
3. High sensitivity (makes it possible to detect a medical problem in the early stages of development, even before the appearance of a specific clinical picture).
4. Identity of the procedure for detecting different pathogens.
5. Speed of obtaining PCR analysis results.
6. The ability to detect not only acute diseases, but also latent infections.
7. The analysis has a low percentage of false positive and false negative results (subject to compliance with all standards, including the collection of biological material).

Pic.9. PCR – diagnostics.

PCR diagnostics allows you to detect all viral diseases known to science at the moment. This also applies to those diseases that can be in the human body for years and not manifest themselves, waiting for the most favorable conditions for the development of the pathological process. Diagnostics of pathogens that develop over a long period of time is especially relevant in gynecology and urology.

Also, PCR tests are widely used in differential diagnostics in pulmonology, gastroenterology, infectology, pediatrics (you can do a full infectious screening for children) and hematology (especially if it is necessary to detect oncogenic viruses).

TOPIC 2. FLOW CYTOMETRY

Flow cytometry is a modern technology for rapid measurement of cell characteristics, their organelles and the processes occurring in them. It is an effective approach to solving many important problems in medicine, cell biology and cell engineering. Advances in the field of fluorescent dyes, the development of laser and computer technologies, and the creation of effective software have led to the widespread use of this technology in medical practice.

Appearance of the BD FACS Calibur flow cytometer

Pic. 10. Flow cytometry.

Flow cytometry is a powerful single cell analysis technique that has found wide application in various fields of science and medicine. The main purpose of studying flow cytometry is to analyze, sort, and quantify cells or particles in samples. Typically, individual cells or populations of cells are examined for various parameters, such as size, cell surface composition, internal molecular content, and other biological characteristics.

Basics of the flow cytometry method:

1. Sample preparation: The samples must be suitable for flow cytometry. Typically, this is a single cell suspension.

2. Flow through: The samples are passed through a thin stream of liquid, where the cells one by one pass in front of a laser.

3. Measurement of parameters: Lasers hit the cells, and different components of the cell or particles scatter and dissect the light. Data on this scattered light signaling for various parameters are collected.

4. Data analysis: The data obtained are analyzed, and information about the cells is presented in the form of histograms, scatter plots, or other types of graphs.

Physical properties of cells (size and cytoplasmic granularity) can be measured on any individual unstained cell. Cells can also be labeled with specific dyes that stain DNA, RNA, or protein, or with a whole set of fluorochrome-conjugated antibodies directed at membrane and intracellular components of cells. The analysis

takes into account both the level of fluorescence of chemical compounds that are part of the cell (autofluorescence) and those introduced into the sample before flow cytometry.

A suspension of cells pre-stained with fluorescent dyes is forced through a capillary under pressure. The cells, picked up by the flow of liquid, line up one after another, forming a “chain”. This is how the principle of hydrodynamic focusing is implemented, thanks to which laminar flow conditions are created without mixing the cell suspension with the surrounding fluid. When such a jet crosses a focused laser beam, then at the point of intersection of the flow and the beam, as a rule, only one cell is detected at the same time, which allows you to avoid artifacts associated with different distances of cells from the point of intersection of the laser beam with the flow.

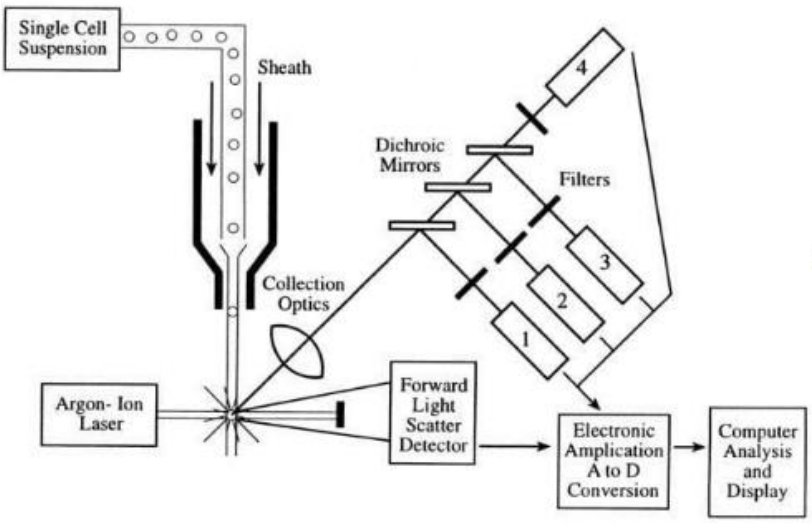
In the measuring chamber of the device, molecules of some cell structures, crossing the beam of a monochrome laser, absorb light of a certain wavelength and go into an excited state. Returning to the initial state after a short time, the cells emit light quanta with other wavelengths. This secondary radiation, which has strictly defined wavelengths for each type of cell or their structures, passing through the optical system of the device is recorded by a photomultiplier, which converts it into electrical signals convenient for computer processing and information storage.

At the moment the laser beam crosses the cell, the detectors record: 1) light scattering at small angles (from 1° to 10°), the obtained characteristic is used to determine the size of the cells;

2) light scattering at an angle of 90°, which allows conclusions to be drawn about the ratio of the nucleus to the cytoplasm, as well as about the heterogeneity and granularity of the cells; 3) fluorescence intensity in several fluorescence channels (from 2 to 18-20) - allows to determine the subpopulation composition of the cell suspension, etc.; 4) fluorescence polarization and particle flight time, which allows to assess the degree of viscosity of cell membranes, which varies depending on their functional state, as well as the degree of asymmetry of the cells or organelles under study.

Two or three fluorescent signals, each indicating the reaction of one marker with a specific recognized antigen, can be recorded together with the forward (FSC-Forward Scatter) and side scatter (SSC-Side Scatter) light signals. Light scatter signals, which characterize the cell size (FSC), and then cytoplasmic and membrane features (SSC), link the results of the fluorescent analysis with morphologically defined populations.

Multiparametric analysis of flow cytometry allows you to reduce the required volume of biological material (up to 100 μl), sample preparation time and actual analysis (seconds) due to high speed. Another advantage of the method is the ability to analyze a large number of cells (up to 108 cells); parameters of rare cells are measured; objective measurement of fluorescence intensity occurs. The possibilities of analyzing the results are increased by the use of statistical and mathematical models.



Flow cytometers take in

Pic.11. flow cytometry method.

So, the advantages of the flow cytometry method are:

1. Speed: Flow cytometry can analyze thousands of cells per second, which allows you to quickly obtain a significant amount of data.

2. Single cell analytics: The method allows you to study cells individually, providing detailed information about each cell in the population.

3. Multiple parametric analysis: Flow cytometry can measure several parameters simultaneously, which allows for more comprehensive analysis of cells.

4. Cell sorting: Flow cytometry can separate individual cells or subpopulations for further study.

The following samples are examined by the flow cytometry method:

• blood;
• bone marrow;
• cerebrospinal fluid;
• joint, pleural and ascitic fluids;
• suspended tissue cells.

When studying flow cytometry, the main goals are:

1. Analysis of cell populations: Determining the composition and number of different cell types in a sample, such as blood, tissues, or cell cultures.

2. Determination of cell marker expression: Studying the presence or absence of specific molecules (markers) on the surface or inside a cell. This allows the identification of certain cell subpopulations and the study of their functions.

3. Analysis of internal cellular processes: Measuring the content and activity of internal components of the cell, such as fluorescent markers or proteins, which can indicate certain functions or stages of cell development.

4. Study of cell cycles and apoptosis: Assessment of the cell cycle and detection of programmed cell death (apoptosis) in cells, which allows for understanding their growth and differentiation processes.

5. Cell sorting: Separation and isolation of individual cells or cell subpopulations for further study or use, such as for cloning or transplantation.

6. Monitoring therapeutic effects: Studying the effects of treatments on cell populations, such as in the treatment of cancer or infectious diseases.

7. Immune response studies: Studying the activity of the immune system, analyzing the functions of immune cells, and detecting responses to infections or immunotherapy.

Overall, flow cytometry is a powerful tool for studying cell populations and the processes occurring in cells, which provides significant opportunities for research in various fields of science and medicine.

How to understand flow cytometry results?

Scientists use flow cytometry to differentiate between different types of cells or microscopic organisms. Although this experimental method is quite simple to perform, the analysis of complex data obtained with a flow cytometer is more difficult due to the many experimental factors and/or cytometer parameters. As such, the flow cytometric data is ordered and visualized using sophisticated professional software such as CELLQuest or FlowJo. Familiarity with flow cytometry techniques, equipment, and software is essential to understanding the results obtained from these experiments.

Clarify the purpose of the experiment by asking, "What question or hypothesis was being investigated?" Make any necessary changes to display the data with appropriate settings (e.g., positive cells, negative gates, fluorescence intensity, cell population, etc.).

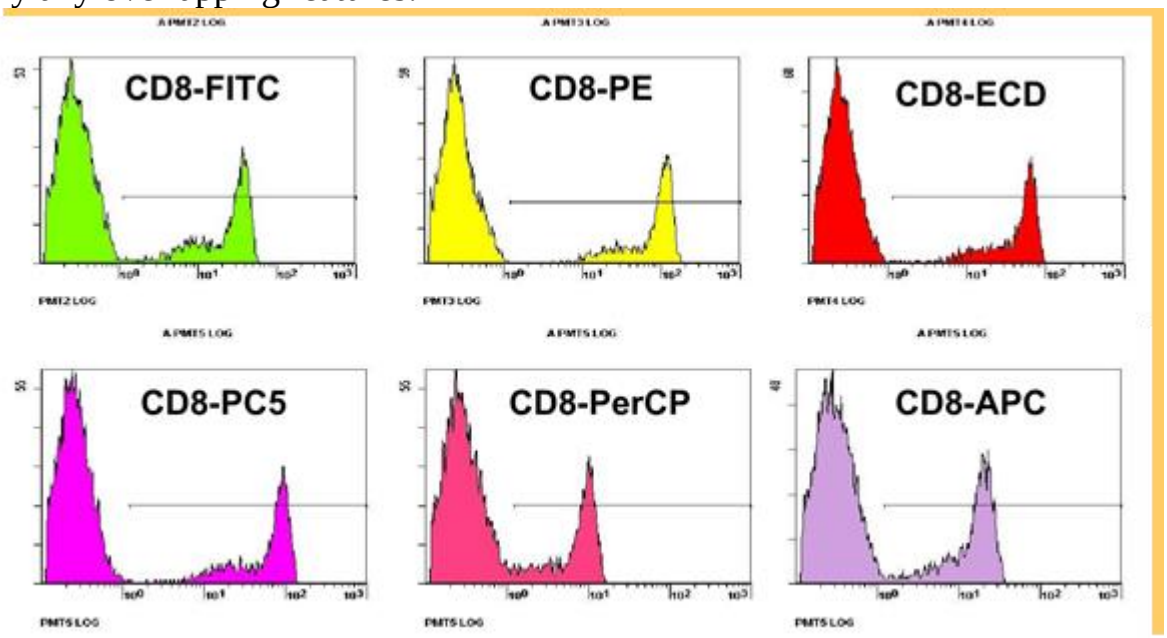
Find the gates. Cells can be grouped or simply grouped on a density plot or contour plot. Groups are often divided based on their identity. If one group stains very intensely for a particular marker or antibody, it is concluded that all members of that group have the identity of a particular cell type expressing that marker. It is common to find cells that are positive for more than one of these markers, and these cells are usually intermediate and are referred to as "double-positive."

Look at the scatter plots. The way the groups of cells are distributed on the scatter plot is an indication of the size of the cells. Cells with a very large or large scatter are usually large cells; however, they may be larger simply because they contain a high proportion of cytoplasm, or they may be larger because they have a very large nucleus. Depending on the biology being studied, this will of course vary widely between experiments.

Look at the numbers. Set up the graphs to display the different parameters on one axis (usually the X axis), while keeping the values on the Y axis. This indicates the proportion of the sample population that is positive for that particular parameter, as a peak will usually be seen in a positively stained sample that will be absent in the negative control. sample.

View multi-parameter histograms. By adjusting the X-axis and Y-axis to represent different parameters that were investigated during the experiment, you can gain a deeper understanding of the properties of the sample. For example, by setting the X-axis to red fluorescence and the Y-axis to green fluorescence, you can calculate quadrant-style gates for the sample to show the four quadrant regions where cells are present and color them red or green. Fluorescence, both colors, or none. This allows

you to separate a heterogeneous sample into its component parts and visualize and quantify any overlapping features.



The main task of flow cytometry in immunology is immunophenotyping of normal and pathological immunocompetent cells, determination of phagocytic activity, intracellular cytokines, intracellular proteins, proliferative activity, study of the cell cycle, assessment of cellular cytotoxicity. The largest number of studies over the past decade has concerned the innate immune system. The use of monoclonal antibodies conjugated to various fluorochromes has led to the development of multiparametric analysis and has significantly simplified the work of specialists in the diagnosis of various disorders of the immune system.

2. Oncology.

Flow cytometry in oncology is a quantitative analysis of intracellular components (DNA); analysis of cell cycle stages; detection of aneuploid clone and determination of its proliferative activity; determination of specific markers; monitoring of patients at risk; assessment of the immune system, which consists in assessing the cellular link of immunity and assessing the functional capacity of immunocompetent cells.

3. Nanoneurotechnology.

In modern nanoneurotechnology, the use of magnetic nanoparticles for transporting biologically active substances and drugs to target cells in the case of external manipulation and in antitumor therapy is extremely promising. The binding of nanoparticles to nerve terminals and platelets is studied using flow cytometry and photon correlation spectroscopy. The size of particles in the preparations was determined by direct (FS), and cytoplasmic granularity by side (SS) light scattering.

4. Cytology.

In cytology, the method is used to determine the cytomorphological affiliation of a cell; assess the activity of intracellular enzymes; determine the expression of surface antigens; analyze the stages of the cell cycle; measure the physiological parameters of the cell - intracellular pH, concentration of free Ca^{2+} ions, potential of

the outer cell membrane. Flow cytometry is used to study the transmembrane exchange of calcium ions in mitochondria, for example, to detect changes in mitochondrial potential and the level of reactive oxygen species, etc. The method is also used to study the exchange of Ca^{2+} ions in isolated mitochondria.

5. Hematology.

Hematology uses this method to analyze the subpopulation composition of peripheral blood cells; count reticulocytes, analyze platelets by specific markers; differential diagnosis of lymphoproliferative diseases and reactive lymphocytosis; diagnosis of acute leukemias; assessment of minimal residual disease.

6. Pharmacology.

The method of flow cytometry in pharmacology creates opportunities for measuring the expression of markers, the activity of intracellular enzymes; determining the stages of the cell cycle in the framework of studying the mechanisms of action of various biologically active substances at the cellular level.

7. Bacteriology.

Flow cytometry is widely used to detect bacterial, fungal and human body cells in the studied samples (in the amount of 10-100 pieces in 1 ml of blood); to determine the sensitivity of microorganisms to antibacterial drugs. Microorganisms exposed to antibiotics (in vivo or in vitro) are compared with control samples of the same strain to establish their viability, as well as changes in nucleic acids, proteins, cell membranes, etc., which allows assessing the degree of antibiotic effect and the point of application of its action. High sensitivity of the method is ensured by the use of monoclonal antibodies labeled with a fluorescent substance.

The method allows monitoring the state of the viral process in HIV-infected patients and can be used to monitor the effectiveness of the therapy.

8. Genetic engineering.

Flow cytometry can also be used in the field of protein engineering to identify cell surface variants of a protein molecule.

9. Biochemistry.

Flow cytometry can be used to measure oxidative stress in somatic cells in workers exposed to welding dust and in other industrial environments. Calculating the oxidative stress index is useful for predicting the consequences of diseases and for determining the effectiveness of preventive measures.

10. Biology.

In biology, in particular in plant breeding (agriculture), the method is used to determine cell ploidy, analyze cell cycle stages, analyze and sort protoplasts. In marine biology, the volumes and distribution of plankton photosynthesis can be analyzed.

11. Ecology.

It is important to monitor the ecological state of natural ecosystems, in particular polydisperse aquatic environments, which are an integral part of a significant number of objects of natural origin. Polydisperse aquatic environments are complex polydisperse systems that include particles of various types, sizes and shapes that are suspended in colloidal solutions and are in complex interaction. These

particles are mainly biological cells and their agglomerates. Scanning flow cytometry allows you to determine the size and refractive index of individual particles and thereby contributes to their identification.

12. Cytoenzymology.

Flow cytoenzymology opens up broad prospects for further identification of damaged or altered cells and allows you to make adequate decisions regarding the effective treatment of detected pathological changes.

The variety of options for using flow cytometry today can be limited only by the imagination of the researcher, and in the diagnostic service - by the analytical needs of the clinic.

TOPIC 3. METHODS OF TOMOGRAPHY

Tomography is a method of obtaining layer-by-layer images of the organs and tissues under study.

The main disadvantage of the classical X-ray method of examination is the summation effect - the effect of superimposing some organs and tissues on others, which interferes with the diagnosis of some pathological processes.

To eliminate the summation effect, various methods of tomography are used.

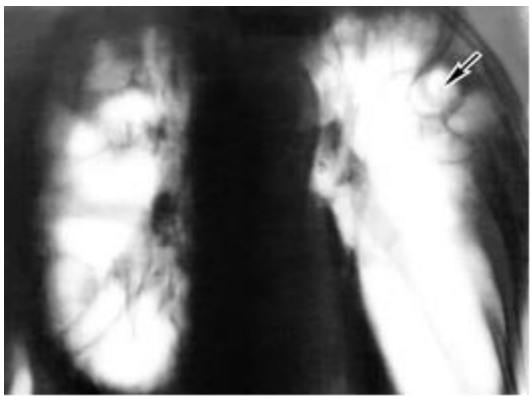
Types of tomography:

- linear
- X-ray computed
- magnetic resonance
- radionuclide tomography techniques (SPECT, PET)

Linear tomography

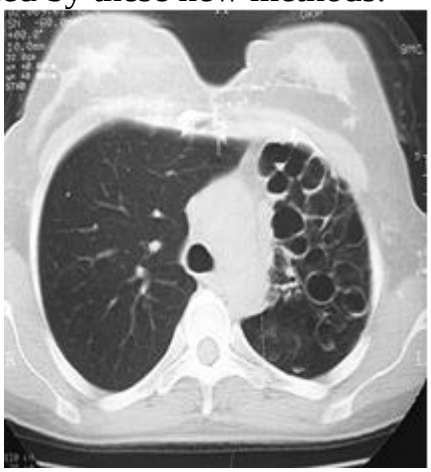
- a method of X-ray examination with obtaining layer-by-layer images of the organs and tissues of the patient under study on X-ray film.

The radiograph produces a summation image of any part of the body. Tomography is used to obtain an image of structures located in the same plane, at the level of a certain layer without the effect of superimposing some organs and tissues on others. This effect is achieved by means of a special technical approach: there is a continuous movement during the shooting in different directions of the X-ray tube emitting a beam of rays and the cassette with the film relative to the object under study. This achieves the selection of a special tomographic slice. Due to the partial elimination of the summation effect, the image quality of the organs at the level of the selected layer improves. In appearance, a linear tomogram differs from a radiograph in the absence of visualization of organs above and below the studied level, the presence of blurring of the layers located above and below this level and a clearer visualization of the object under study in the plane of the tomographic slice. For example, on a linear tomogram of the lungs, there is no visualization of the ribs. Linear tomogram: lung cysts.



Pic. 12. Linear tomogram: lung cysts.

Linear tomography helps to more accurately determine the localization, prevalence, nature and structure of the pathological process, to detect small pathological formations and cavities. Unlike linear tomography, X-ray computed tomography and magnetic resonance imaging allow almost completely eliminating the summation effect, therefore, currently linear tomography is rarely used, being replaced by these new methods.



Pic. 13. Computed tomography of the thoracic cavity: lung cysts.

COMPUTED TOMOGRAPHY

Computed tomography is an X-ray examination method

Computed tomography is an X-ray examination method based on computer processing of a multitude of X-ray images,

with the production of axial layer-by-layer slices of the examined organs and tissues of the patient.

Computed tomography is an X-ray method based on the use of X-rays. X-ray examination is a method of radiation diagnostics, in which X-rays are used to obtain diagnostic images.

Types of radiation

used in radiation diagnostics are non-ionizing (thermal, resonance, ultrasonic waves) and ionizing (X-rays, radioactive elements).

Biological effect of radiation. All radiation, both non-ionizing and ionizing, are characterized by biological effects, since they are capable of causing changes in living organisms. However, the energy of ultrasonic waves and electromagnetic

vibrations used in diagnostics is much lower than the energy that is accompanied by mechanical and chemical reactions of tissues. To date, no harmful effects of ultrasound, a stable magnetic field and high-frequency radio waves on the body of biological creatures, including humans, have been registered, so they are considered practically harmless, but the question of their biological effect continues to be studied. The biological effect of ionizing radiation has been known since the end of the 19th century, when in 1895 the German physicist K.V. Roentgen discovered a new type of invisible radiation capable of penetrating deep into tissues and cells, and in 1896 A. Becquerel established that uranium is capable of emitting rays similar in properties to those discovered by Roentgen. Ignorance of the harmful properties of ionizing radiation led to the injury of dozens and hundreds of people. In 1895, Roentgen's assistant William Grube received a radiation burn of his hands. The strong effect of radium radiation was experienced by Henri Becquerel himself. A test tube with radium, which was in the pocket of Henri Becquerel's vest, caused redness of the skin of the abdomen with the subsequent appearance of ulcers.

Stages of the biological effect of ionizing radiation on an object:

1. Physical stage - during which the absorption of radiation energy occurs by the irradiated medium, in which excited and ionized molecules (proteins, carbohydrates, fats, nucleic acids, water, various low-molecular organic and inorganic compounds) appear.

2. Physico-chemical stage - in this stage, the absorbed energy migrates along macromolecular structures and is redistributed between excited and ionized molecules, causing the destruction of chemical bonds where these bonds are less strong, and new ions, solvated electrons and free radicals appear in the microenvironment.

Chemical stage - during this stage, the formed ions and free radicals interact with each other and with surrounding molecules. As a result, new products are formed - superoxide anion, hydroperoxide, hydrogen peroxide, atomic and singlet oxygen, which are strong oxidants of organic substances of the biosubstrate. When the products of water radiolysis affect amino acids, proteins, carbohydrates, nucleotides, phospholipids, DNA, organic free radicals are formed. Major structural damage occurs, with the processes occurring in DNA, protein and phospholipid molecules being of greatest importance for the further fate of the irradiated cell. In protein macromolecules, the action of ionizing radiation leads to a violation of the primary structure: rupture of disulfide bridges, hydrogen bonds, peptide chain; formation of crosslinks between peptide chains, oxidation of sulfhydryl groups and aromatic amino acids. The result of these processes is a change in the secondary and tertiary structure of proteins, which in turn leads to a violation of their biological properties, including enzymatic, hormonal, receptor activity. The relative chemical composition of membrane phospholipids, their viscosity, permeability, and many physicochemical characteristics change, with subsequent disruption of vital functions for the cell - barrier, receptor-signaling, regulatory, transport, etc. Damage to the membranes of mitochondria, microsomes, lysosomes, and endoplasmic reticulum causes disruption of the structure and function of these formations and cells as a

whole. Damage to lysosomal membranes and the escape of proteases beyond their boundaries contribute to the activation of proteolysis processes in the early stages after irradiation. Damage to nuclear DNA develops: single-strand breaks, base damage, double-strand or double breaks, disruption of the secondary structure and supramolecular organization, which lead to disruption of the structure and functions of the cell. There is inhibition of cell growth and division, dystrophic changes, and even death.

4. Biological stage - the formation of damage at the cellular, tissue, organ and organism levels, the formation of remote consequences of radiation. Changes in the chromosomal apparatus of the cell affect its hereditary properties: they lead to radiation mutation, in somatic cells - to the appearance of cells with new qualities, that is, cells - sources of tumor diseases. Mutations in germ cells are detected in subsequent generations, which leads to the growth of hereditary diseases.

However, the effect of ionizing radiation on different biological objects is not the same. Each type of cell and tissue has its own radiosensitivity or radioresistance - a measure of sensitivity or resistance to the action of ionizing radiation.

The radiosensitivity of tissues is directly proportional to the proliferative activity and inversely proportional to the degree of differentiation of its constituent cells (Bergonnier-Tribondo rule). The most radiosensitive tissues in the body are those containing poorly differentiated cells that actively multiply.

By the degree of radiosensitivity, from the most radiosensitive to the most radioresistant, the tissues of the body are arranged as follows:

- myeloid, lymphoid,
- epithelium: germinal, intestinal and integumentary,
- muscle, nervous, cartilage and bone tissue.

Also, the radiosensitivity of a cell, tissue and organ depends on the type of radiation that affects them, the stage of the cell's mitotic cycle, the degree of oxygenation, the functional state (usually increases with increased functions), as well as on external factors: temperature, oxygen and water content.

Thus, any use of ionizing radiation for medical purposes requires mandatory justification, compliance with radiation safety rules, radiation protection of patients and medical personnel.

Properties of X-rays X-rays have the following properties:

- penetrate opaque bodies;
- cause the glow of some chemical compounds;
- decompose silver halide compounds;
- change the electrical conductivity of semiconductor plates;
- form ions.

These properties are widely used in obtaining medical images. X-rays occur in an X-ray tube, which is a glass cylinder with a high degree of vacuum inside it. There are two electrodes in the cavity of the tube: a cathode and an anode. Electrons appear on the cathode, which are accelerated in the space between the cathode and the anode. The accelerated electrodes are slowed down on the anode, due to which X-rays appear.

The X-ray tube is a component of the apparatus that has a tripod on which the X-ray tube is held, a place for placing the patient, a transformer that supplies high and low voltage current to the apparatus, a control panel, and a screen-capturing device.

The X-ray method of research is a method of studying the structure and function of various organs, based on the quantitative and qualitative analysis of a beam of X-rays that have penetrated the human body.

Formation of an X-ray image

The basic scheme of obtaining an image consists of:

• generation of rays in the X-ray tube;

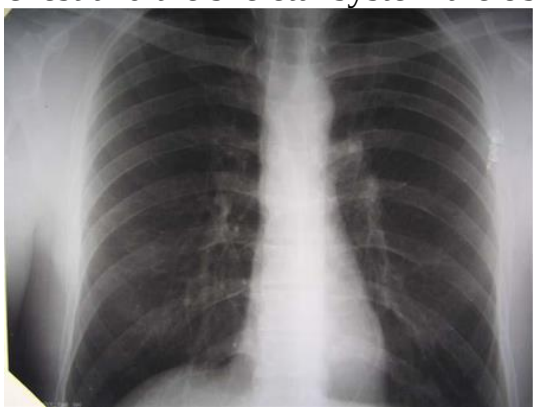
• directing the rays at the patient;

• obtaining an invisible X-ray image after various absorption and scattering of rays when passing through the object;

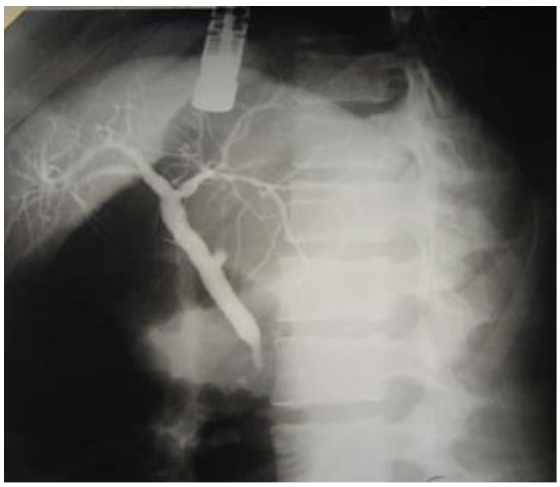
• obtaining a visible image.

Formation of an X-ray image of the organ under study is based on the inhomogeneous absorption of radiation by tissues, and as a result - the attenuation of the X-ray beam when passing through tissues of different densities. Inhomogeneous attenuated radiation falls on the receiving system - a fluorescent screen or X-ray film.

Principles of natural and artificial contrast. Obtaining an X-ray image of organs is possible due to natural contrast, if the organs of the body absorb X-ray radiation to a different extent (significantly more or less) than the surrounding tissues. Bones absorb X-rays to a large extent and intensively attenuate them, the lungs, as an air medium, transmit rays and do not attenuate X-ray radiation, and soft tissues occupy an intermediate position between dense and air structures in terms of the degree of attenuation of X-ray radiation. Due to natural contrast, images of the organs of the chest and the skeletal system are obtained.

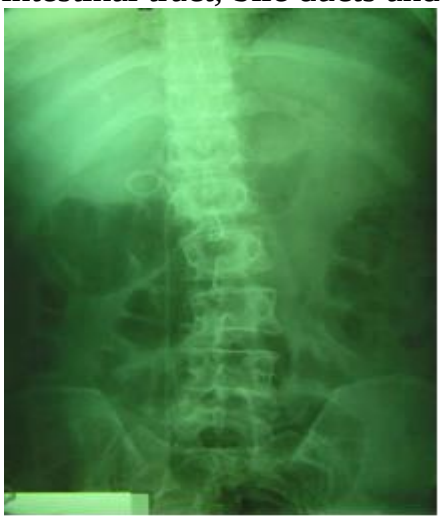


Pic. 14. Some organs and tissues of the body absorb X-ray radiation to almost the same extent.



Pic. 15. Radiograph of the abdominal cavity and urinary system.

To obtain an image of such organs that do not have natural contrast, special techniques are used, which are based on an artificial change in the transparency of the studied organs and tissues for X-ray radiation. This phenomenon is called artificial contrast. For example, organs that do not have natural contrast (organs of the gastrointestinal tract, bile ducts and urinary tract) require artificial contrast.



Pic. 16. X-ray of the biliary tract after their artificial contrast.

Methods using artificial contrast

Artificial contrast is carried out by introducing special radiopaque agents into the human body that attenuate X-ray radiation to a greater extent than surrounding tissues, or, conversely, practically do not attenuate X-ray radiation.

Radiopaque agents are divided into:

1. Those that do not attenuate X-ray radiation: - carbon dioxide, - air
2. Those that attenuate X-ray radiation:

• do not contain iodine (water-insoluble) - barium sulfate,

• containing iodine:

a) fat-soluble,

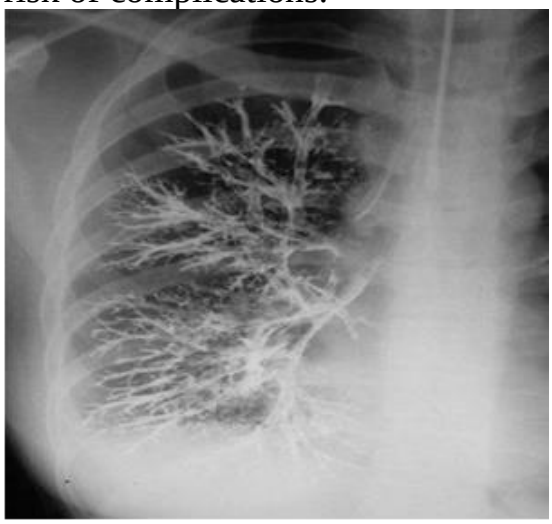
b) water-soluble:

Techniques with artificial contrast are used for X-ray examinations of the abdominal cavity, retroperitoneal space, and cardiovascular system. Under artificial contrast conditions, the gastrointestinal tract is examined with the introduction of an aqueous suspension of barium sulfate into the cavities, and in some cases - iodine-containing preparations. Examination of the urinary and biliary organs is carried out by parenteral or retrograde administration of iodine-containing radiopaque substances.

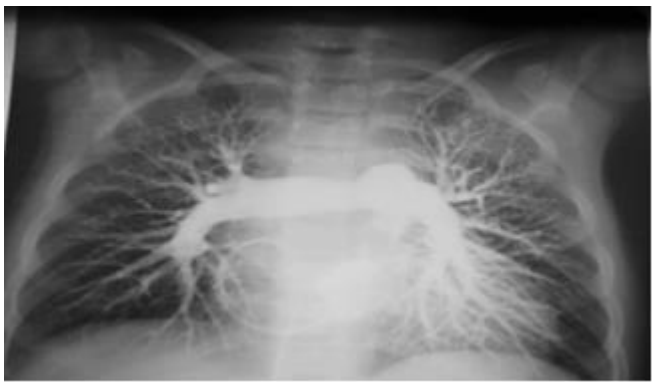
Modern iodine-containing radiopaque substances are divided into ionic (urografin, hipac), which form charged compounds in a liquid medium, and non-ionic (ultravist, omnipak, visipak), which are electrically neutral. Ionic radiopaque compounds have a higher osmolarity compared to blood plasma.

Iodine-containing radiopaque substances can cause side effects due to high osmolarity and chemotoxicity. Radiopaque iodine-containing radiopaque substances can cause anaphylactoid reactions, electrolyte disturbances and changes in hemodynamics, impaired erythrocyte aggregation, damage to the vascular endothelium, impaired kidney function, therefore contrast studies may have contraindications - allergic predisposition, renal failure, severe heart failure, arrhythmia, thyroid dysfunction, epilepsy.

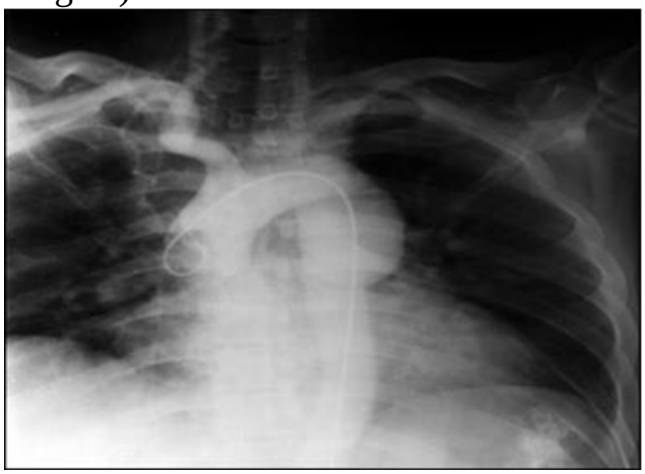
When choosing iodine-containing contrast agents, one is guided by the degree of their contrasting effect and their harmlessness to the patient. The optimal use of isoosmolar blood plasma non-ionic iodine-containing radiopaque contrast agents is optimal, which, compared to ionic ones, are less toxic, have a less pronounced vasodilating effect, release histamine to a lesser extent and deform erythrocytes, inhibit cholinesterase activity, i.e. allow the use of contrasting techniques with a lower risk of complications.



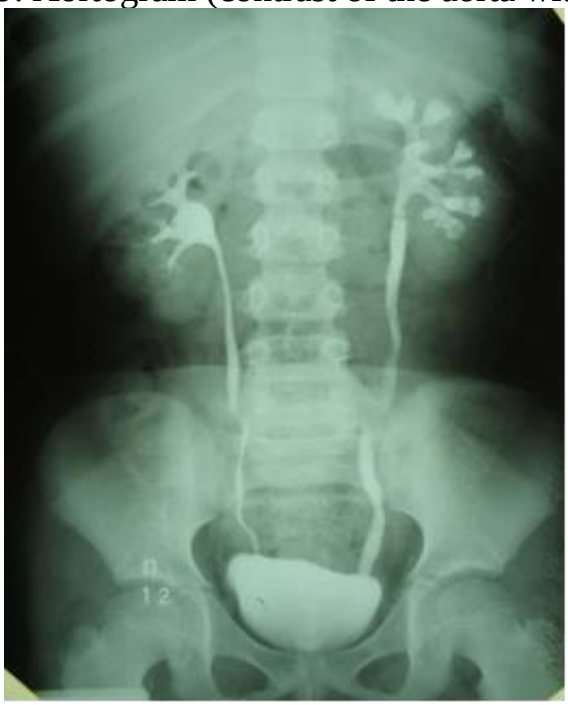
Pic. 17. Angiopulmonogram (contrast of the pulmonary artery and its branches with an iodine-containing contrast agent).



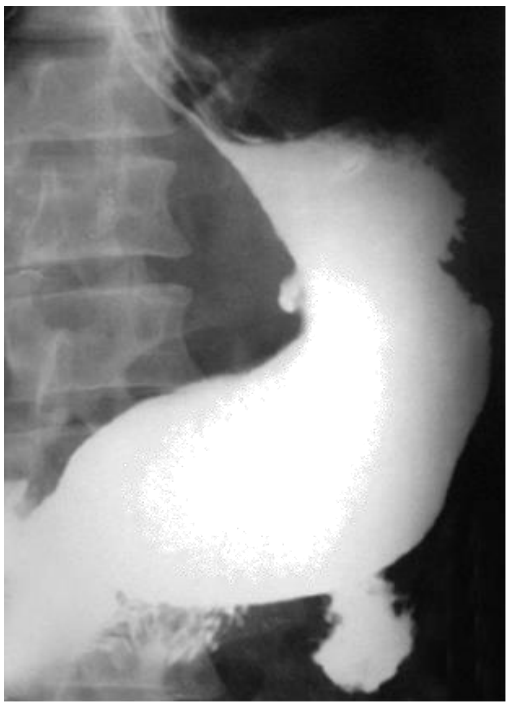
Pic. 18. Bronchogram (contrast of the bronchial tree with an iodine-containing contrast agent).



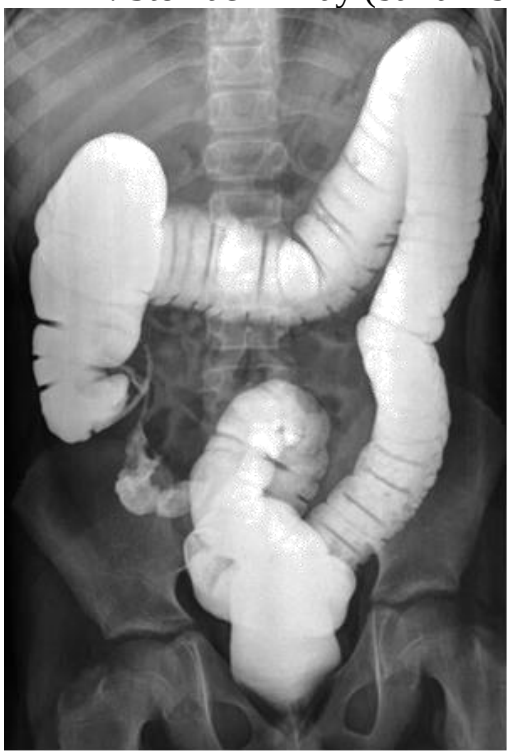
Pic. 19. Aortogram (contrast of the aorta with an iodine-containing contrast agent).



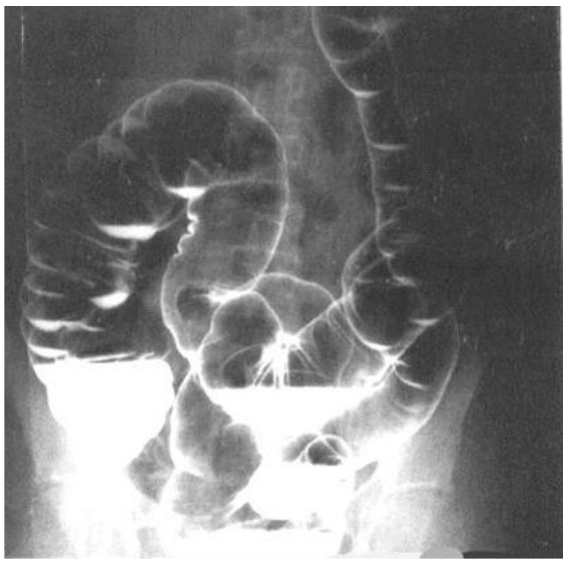
Pic. 20. Excretory urogram (contrast of the urinary system with an iodine-containing contrast agent).



Pic. 21. Stomach X-ray (barium sulfate contrast).



Pic. 22. Irrigogram (contrast of the colon with barium sulfate).



Pic. 23. Irrigogram (double contrast with barium sulfate and air).

Methods of obtaining an X-ray image

• **radiography** - on X-ray film;

• **electroradiography** - on a selenium semiconductor plate, then transferred to paper;

• **fluoroscopy** - the image is obtained on a fluorescent screen;

• **X-ray television fluoroscopy** - an image on a television screen using an X-ray electron-optical converter;

• **digital means of radiography and fluoroscopy** - using an electron-optical and analog-to-digital converter on a television screen or photographic film and paper;

• **computed tomography** - using a detector sensor (scintillation, gas-discharge, or semiconductor) on a television screen or photographic film or paper.

Physical basis of X-ray CT. Computed tomography uses X-rays, so X-ray CT is based on the ability of different organs and tissues of the human body to attenuate X-ray radiation unevenly. In the process of passing through tissues, X-rays are attenuated, partly due to energy absorption, partly due to scattering.

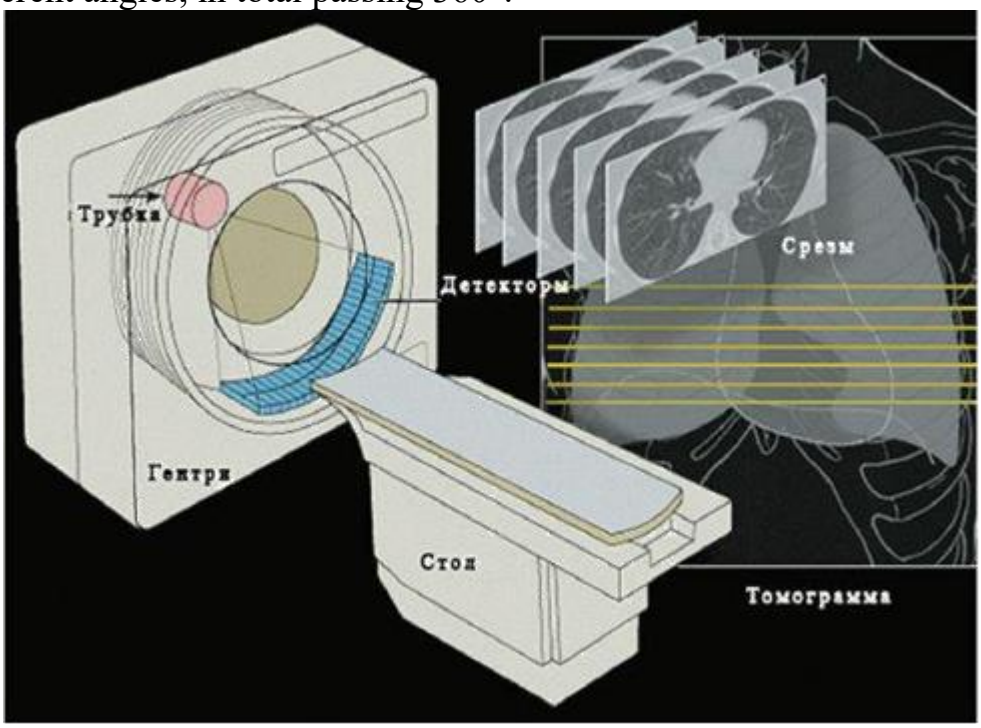
Attenuation can be described by the following equation: $I=I_oc-\mu d$,

where I is the intensity of the radiation that was transmitted (radiation at the exit from the tissue), I_o is the intensity of the incident radiation (at the entrance to the tissue), μ is the so-called total linear attenuation coefficient for the tissue, d is the distance that the radiation has passed through the tissue (tissue thickness). The attenuation coefficient μ is determined by the atomic number and electron density of the tissue. The higher the atomic number and electron density, the higher the attenuation coefficient. Thus, atomic number and electron density are two parameters that determine the quality of tissue in terms of X-ray attenuation. It should be noted that the attenuation coefficient also depends on the energy of the X-rays.

Thus, the physical foundations of CT and X-ray techniques are identical, but these methods differ in the principle of obtaining and processing diagnostic information.

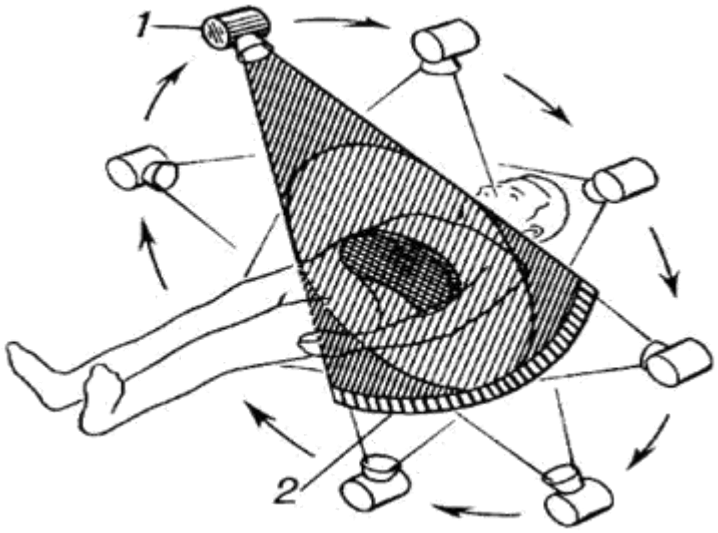
Pic.24. Computed tomography.

The basis of a CT scanner is an X-ray tube, but it emits a fan-shaped beam of X-rays directed perpendicular to the long axis of the body of the person being examined. The X-ray tube rotates around the patient and returns to the patient's body at different angles, in total passing 360°.



Pic. 25. Diagram of how a computed tomography scanner works.

X-rays, passing through the object under study, are unevenly attenuated and recorded by a system of detectors. Detectors record the degree of attenuation of X-ray radiation and convert X-ray radiation into electrical signals that are directly proportional to the energy of X-ray photons. All signals from all detectors are recorded in the computer's memory, on the basis of which, as a result of post-processing, a planar image of an axial section of the organ under study is constructed - a computer tomogram.

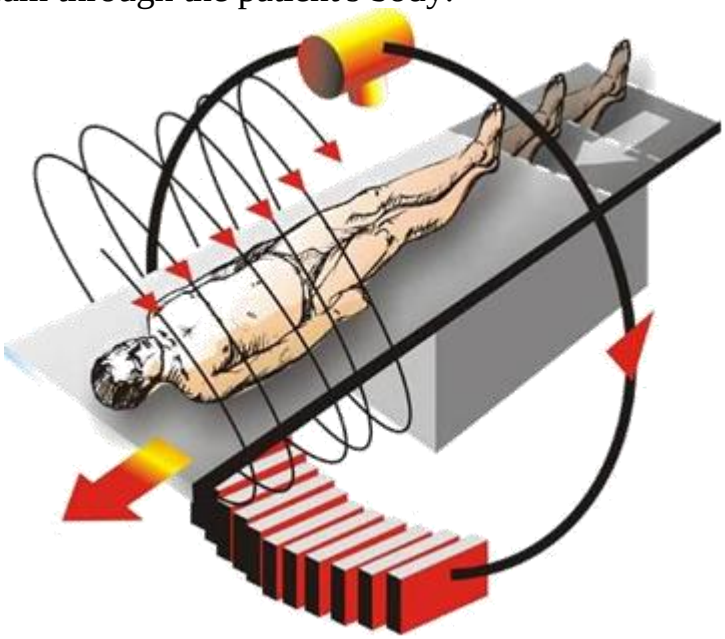


Pic. 26. Schematic image of a computed tomography scanner.

A computed tomography scan is ultimately a series of axial tomographic slices of the organ and body region under investigation, such as the "Pyrogov" type, which are subject to diagnostic analysis.

The resulting CT image is completely objective, it can be evaluated and studied on the device monitor, recorded on paper or X-ray film, and compared and contrasted over a period of time, if there is a complex diagnostic case.

In modern spiral computed tomography scanners, the rotation of the X-ray tube and the movement of the patient inside a circular frame, called a gantry, occur simultaneously and continuously. The result is a spiral movement of a fan-shaped X-ray beam through the patient's body.



Pic. 27. Scheme of the principle of operation of a spiral computed tomography scanner.

This reduces the examination time, reduces radiation exposure, and makes it possible to obtain reconstructive images in different slices: frontal and sagittal, as

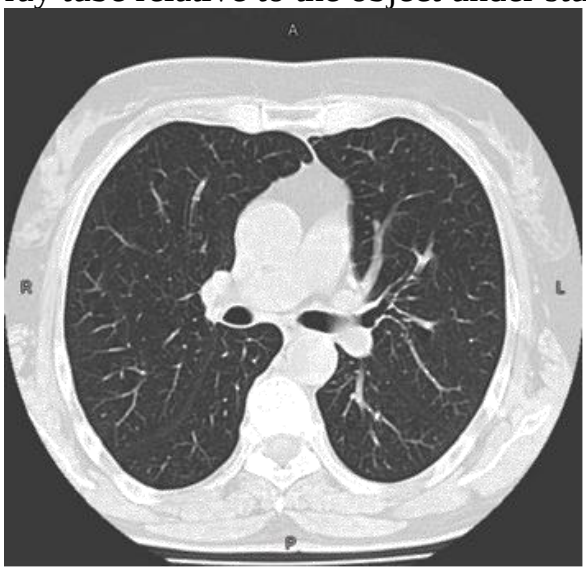
well as conduct scanning using contrast techniques. The latest multi-slice (multi-slice) computed tomography scanners, in which up to 40 slices are obtained per rotation of the X-ray tube, allow for the reconstruction of high-quality three-dimensional images.

Advantages of X-ray computed tomography

Advantages of X-ray CT compared to radiography

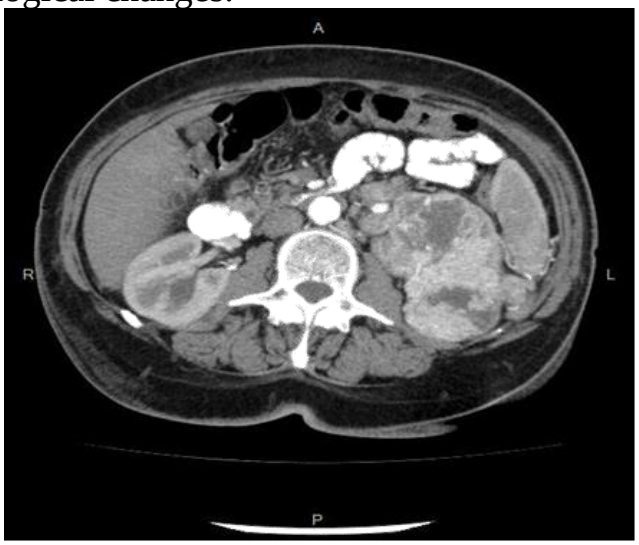
Compared to classical X-ray methods, CT has a number of advantages, the main of which are:

Absence of summation effect: CT allows for a clear layer-by-layer image of the object due to the fact that the examination mode occurs with a 360° rotation angle of the X-ray tube relative to the object under study.



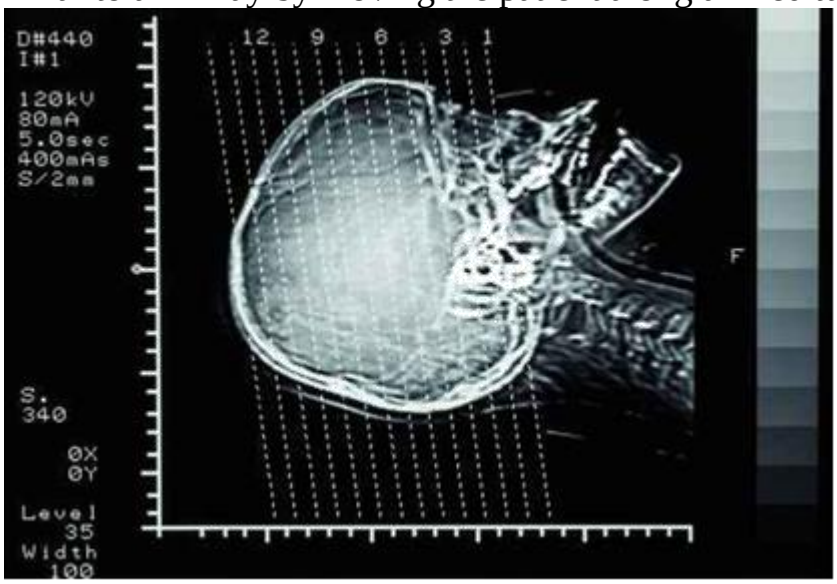
Pic.28. Axial layer-by-layer imaging of the organs of the thoracic cavity.

Allows you to judge not only the condition of the organ being examined, but also the relationship of the pathological process with organs and tissues located nearby, for example, tumor invasion into neighboring organs, the presence of other pathological changes.



Pic. 29. Computed tomography (tumor of the left kidney with invasion).

Allows you to obtain topograms, that is, a longitudinal image of the studied area similar to an X-ray by moving the patient along a fixed tube.

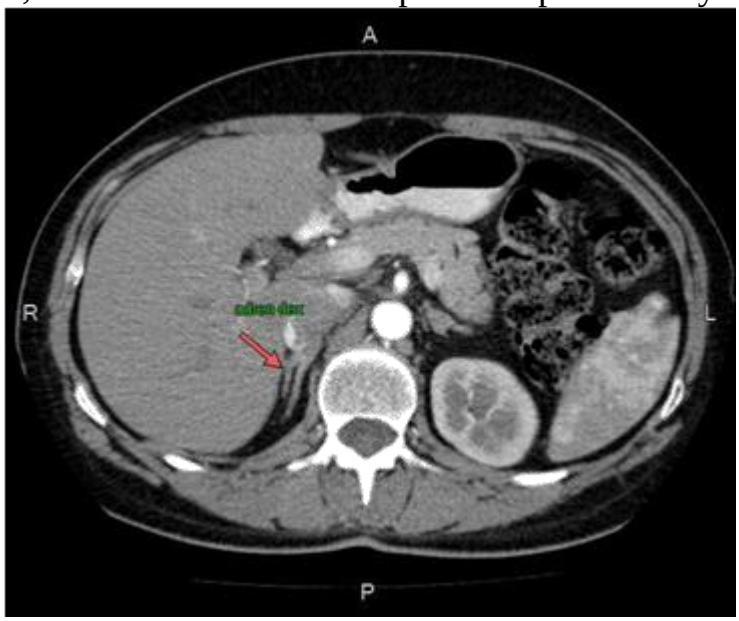


Pic. 30. Topogram.

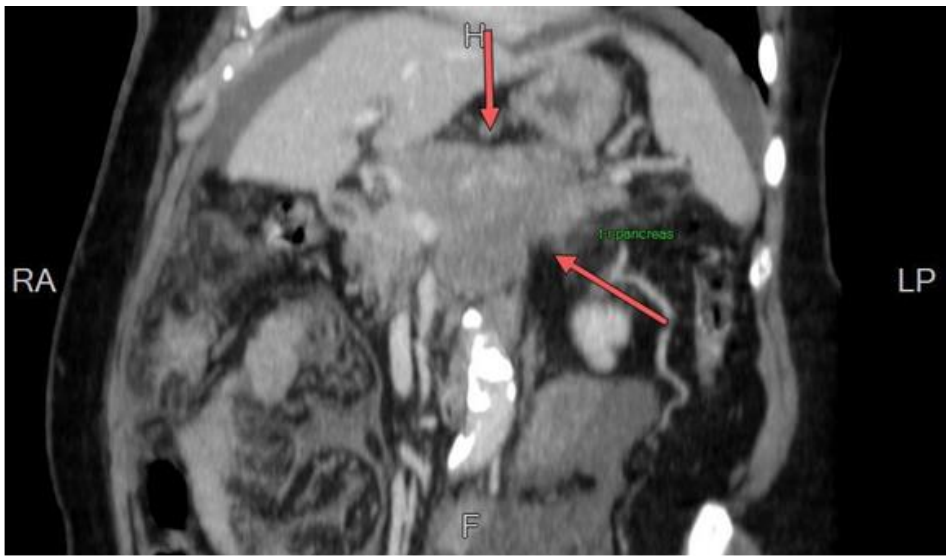
Topograms are used to establish the length of the pathological focus and determine the number of slices.

High resolution - the ability to distinguish a greater number of details in the image of the studied object compared to radiography. CT is characterized by high sensitivity, which allows differentiating individual organs and tissues from each other in density within 1-2%, and on 3-4 generation tomographs - up to 0.5%.

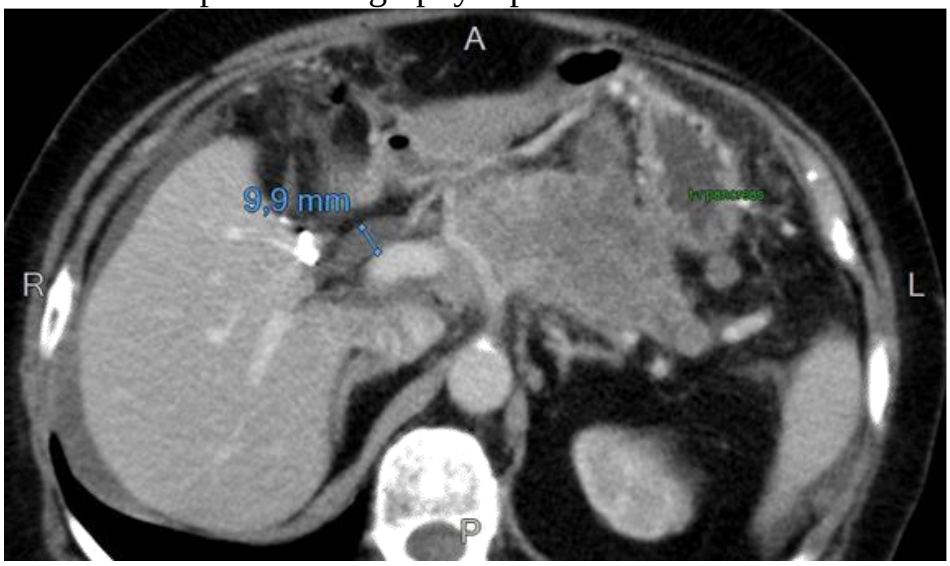
Due to the high resolution and the absence of the summation effect, it is possible to visualize structures that are projected onto the image of other organs and practically do not give an image on routine radiographs (brain, pancreas, lymph nodes). To increase the resolution of CT, contrast enhancement techniques using water-soluble non-ionic X-ray contrast agents (ultravist, omnipak, visipak, etc.) can be used, which are administered per os or parenterally.



Pic. 31. Computed tomography of the right adrenal gland.



Pic. 32. Computed tomography – pancreatic tumor



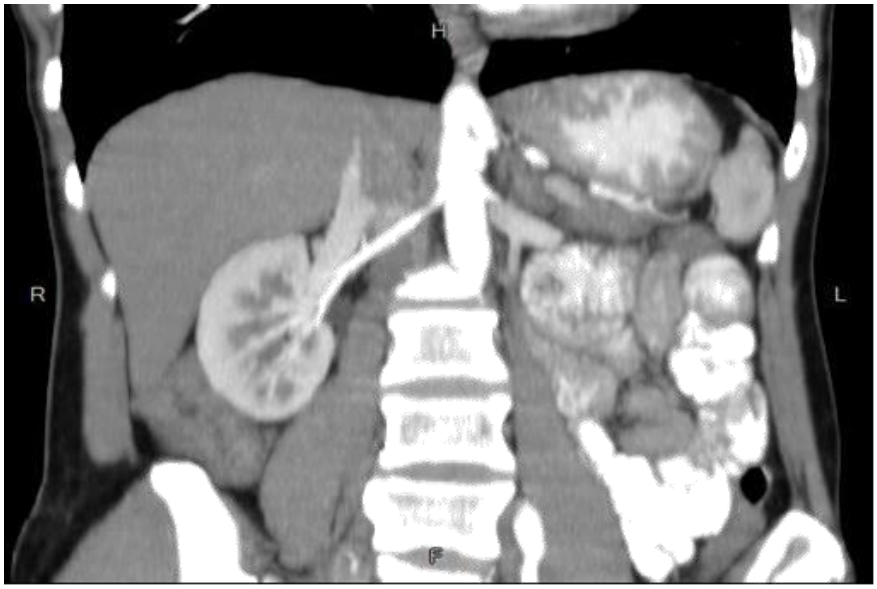
Pic. 33. Computed tomogram of choledochal dilatation in pancreatic tumor.

The ability to quantitatively determine the X-ray density of the studied object: this allows you to supplement the visual assessment of the computed tomography picture with an analysis of the density of visualization structures. The technology of processing signals from the detectors of a computed tomograph allows you to accurately measure the attenuation of X-ray radiation by different areas of tissue in numerical value on a conventional linear scale from -1000 to +3000. This attenuation is measured in Hounsfield units. The value "0" on the Hounsfield scale (H units) is taken as the attenuation of X-ray radiation by water, and -1000 - by air.

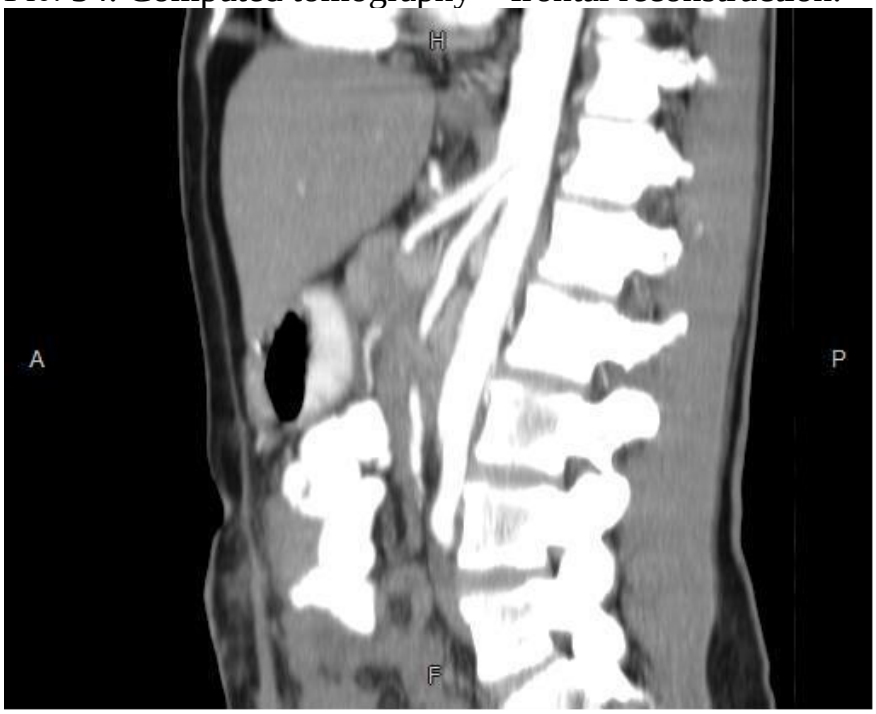
The assessment of quantitative values, expressed in Hounsfield units, allows in a number of clinical situations to determine the nature of the detected changes and to conduct differential diagnostics between different types of pathologies, because it makes it possible to distinguish, for example, soft tissues, liquid structures, adipose tissue, etc.

The possibility of performing reconstruction of primary images - obtaining slices in the frontal, sagittal and other necessary planes, as well as the formation of

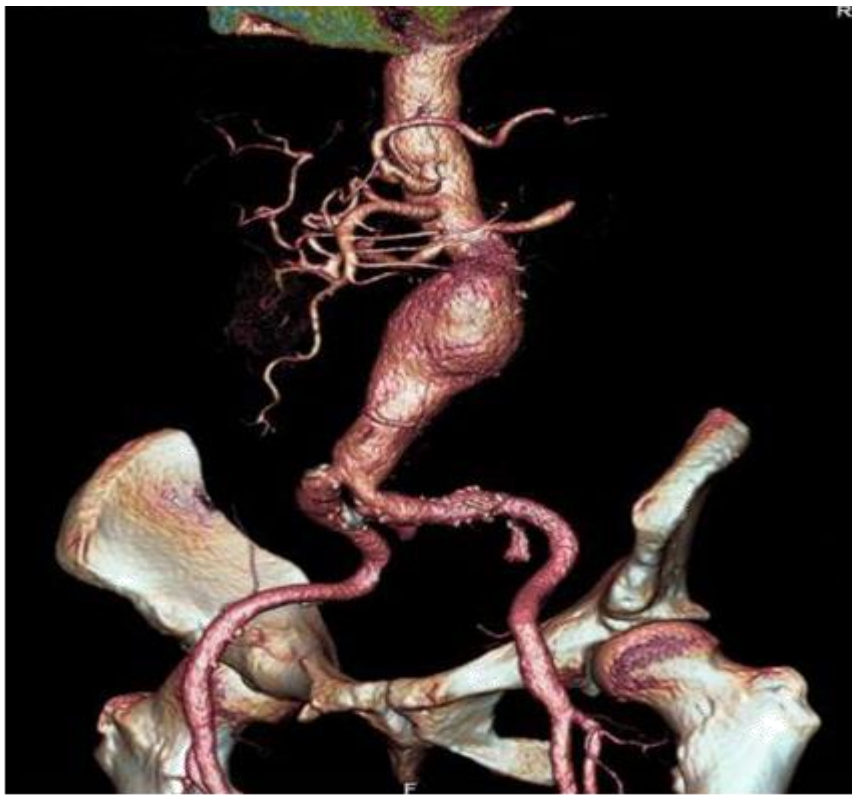
three-dimensional (volumetric) images - allows to determine the exact topography and mutual arrangement of organs and pathological structures.



Pic. 34. Computed tomography – frontal reconstruction.



Pic. 35. Computed tomography – sagittal reconstruction.

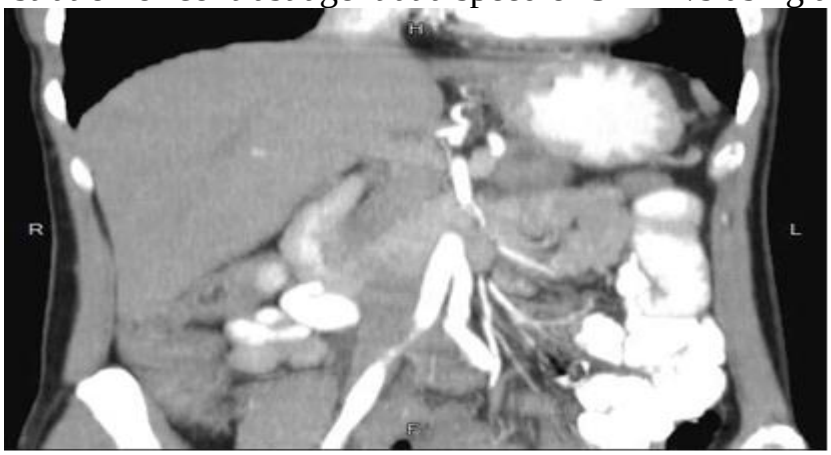


Pic. 36. Computed tomography is a three-dimensional reconstruction.

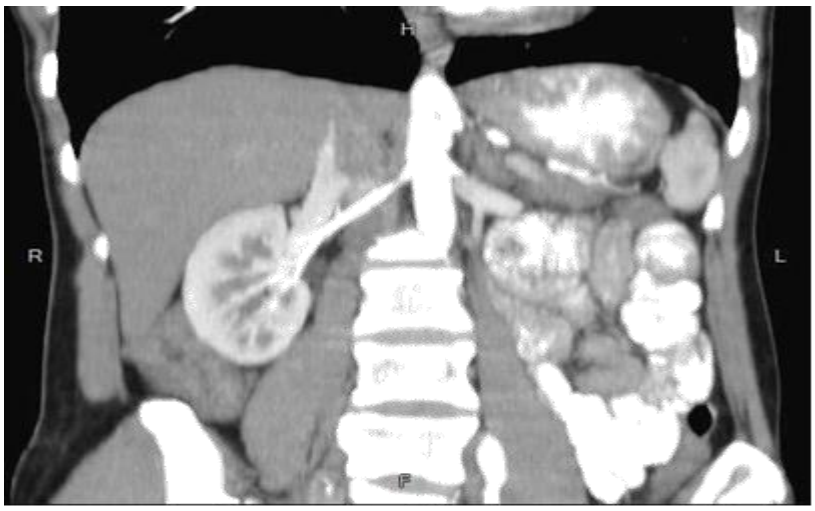
The possibility of performing contrast phase-by-phase image enhancement and non-invasive angiography. Radiopaque (water-soluble) contrast agents are administered parenterally using a conventional syringe or bolus administration is used. With the bolus method of contrast agent administration, automatic syringes - injectors are used to ensure effective phase-by-phase contrast of the studied object, which provide rapid administration of a relatively large volume of radiopaque agent (about 100 ml) at a strictly specified speed (3-4 ml/s).

Artificial contrast in computed tomography

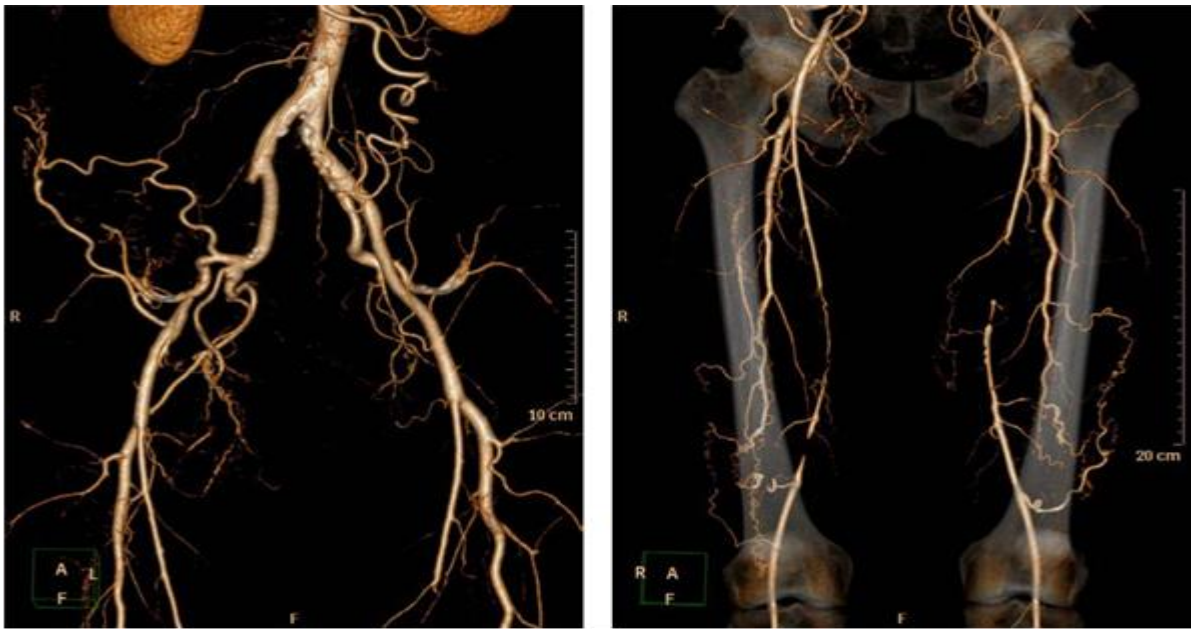
CT angiography - a study of major vessels with preliminary intravenous contrast, which is performed using catheterization of the cubital vein and bolus administration of contrast agent at a speed of 3-4 ml/s using an automatic syringe.



Pic. 37. CT angiography of the abdominal aorta and its branches (frontal reconstruction).



Pic. 38. CT angiogram of the renal arteries (frontal reconstruction).



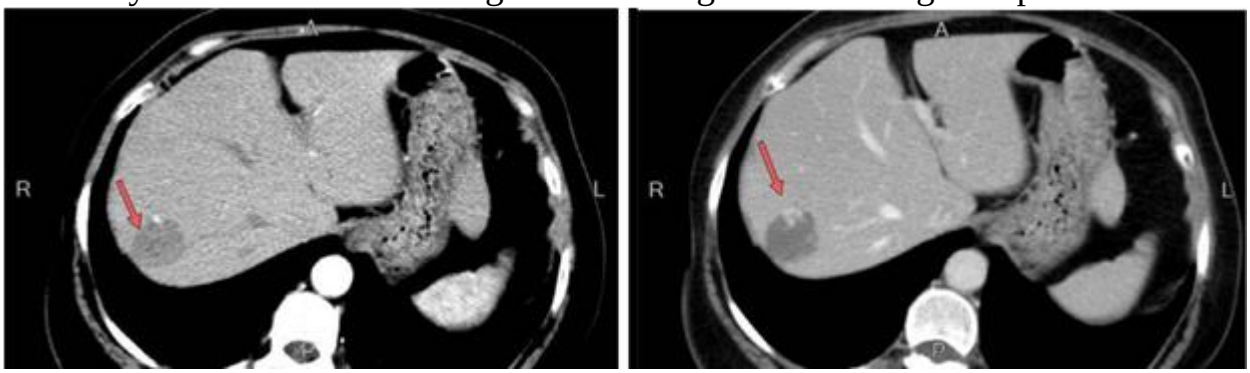
Pic. 39. CT angiograms of the lower extremities in a patient with atherosclerotic arterial disease.

Phase-by-phase contrast - a phase-by-phase study of the organ under study after a previous bolus injection of a radiopaque substance into the patient's vascular bed. Intravenous bolus (rapid and in large quantities) administration of a radiopaque substance is necessary to create its high concentration in a certain area of the vascular bed.

The study is performed in three phases - arterial (maximum contrast of the arteries), parenchymal (contrast of the organ parenchyma) and venous (maximum contrast of the veins) depending on the time of passage of the contrast through the corresponding link of the vascular network. In each clinical case, the need to obtain an image in a certain phase is determined by the radiologist depending on the tasks set before him.

The effect of contrast enhancement is based on the different blood supply of normal and pathologically altered tissue, which causes a different degree of their contrast. Since different pathological formations contrast differently depending on the

phase of the study, it is possible to judge their nature. Phase-by-phase contrast is necessary for the differential diagnosis of malignant and benign neoplasms.



Pic. 40. Computed tomograms with contrast: hepatic hemangioma in the arterial phase (artery visualization) and parenchymal phase (contrast agent accumulation) in hemangioma.

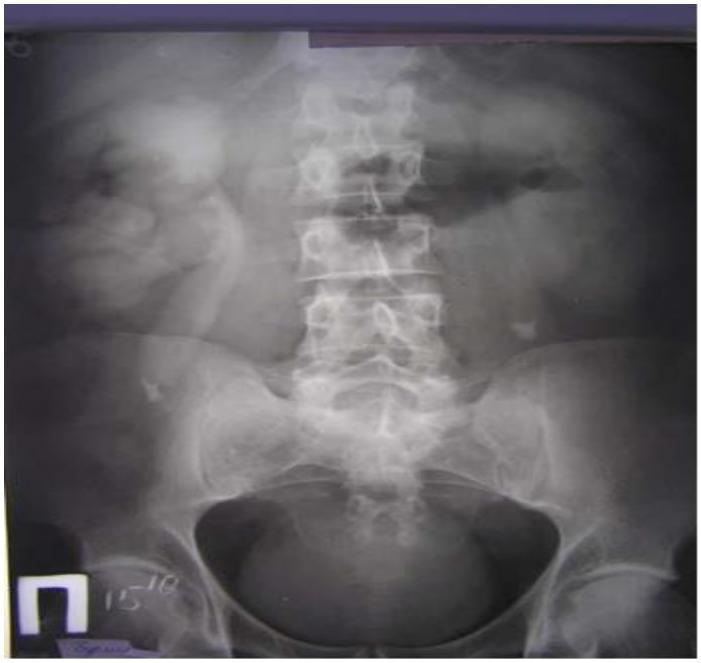
The goals of phase-contrast:

1. improves visualization of the pathological formation;
2. for differential diagnosis of various pathological processes;
3. for assessment of the relationship between the pathological focus and adjacent vessels;
4. to clarify the spread of the process.

Images obtained with CT

With the help of any medical imaging methods, diagnostic radiological images are obtained:

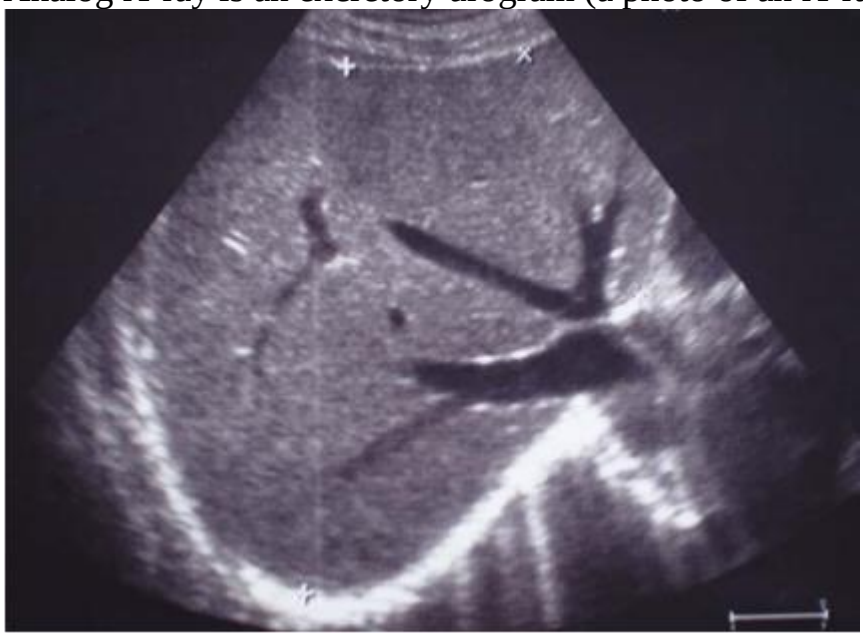
Analog:	Digital:
Roentgenograms	Obtained using a computer
Scintigrams	
Thermograms	



Pic. 41. Analog images carry information of a continuous nature.

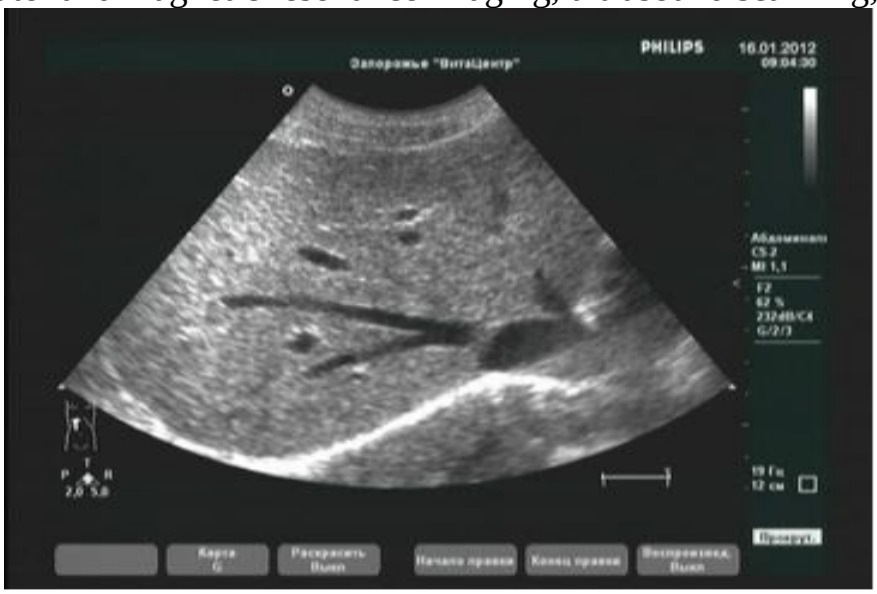
Analog X-ray images are obtained using classical X-ray diagnostic methods (radiography, fluoroscopy, fluorography) on fluorescent screens or on a special X-ray film - a radiograph.

Analog X-ray is an excretory urogram (a photo of an X-ray film on a negative).



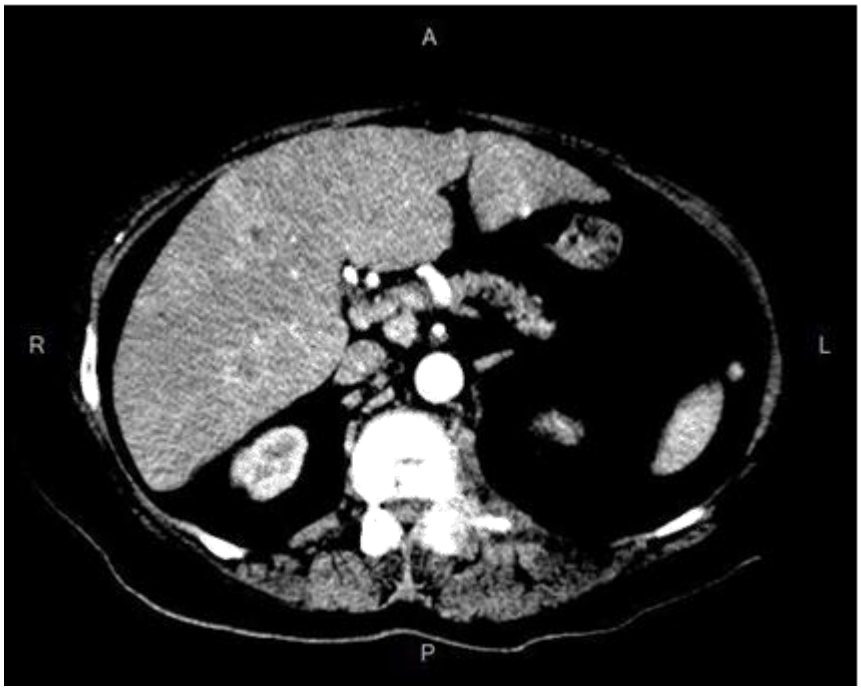
Pic. 42. Analog sonogram of the liver (photo of a sonogram taken on thermal paper).

Digital images are obtained using a computer. These images are obtained by computer and magnetic resonance imaging, ultrasound scanning, digital radiography.

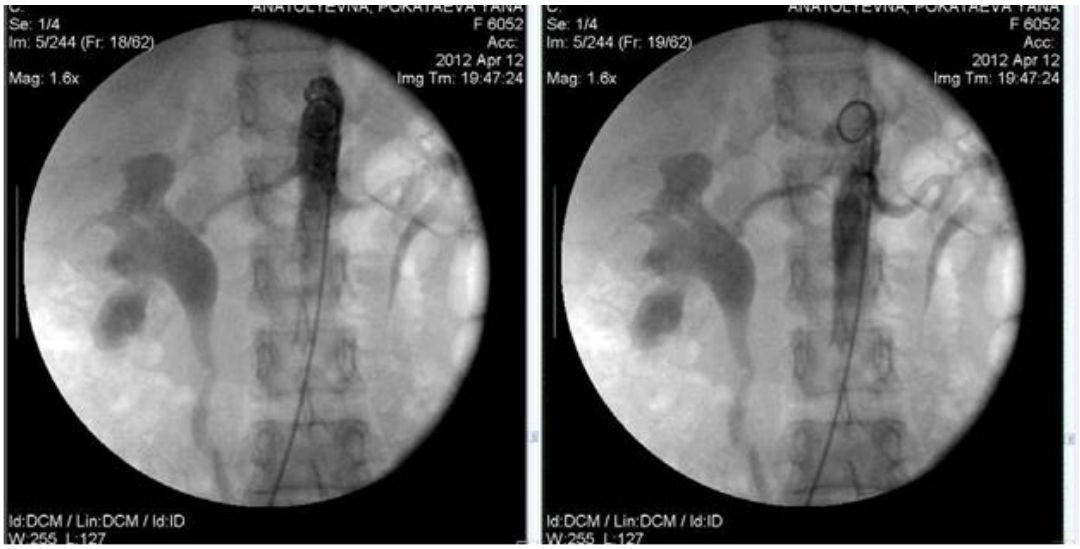


Pic. 43. Digital liver sonogram.

These include digital radiography and fluoroscopy, fluorography, and video recording using an electron-optical transducer.



Pic. 44. Digital computed tomography (liver metastases).



Pic. 45. Digital angiogram of the renal arteries.

When passing through the human body, a beam of X-ray photons is attenuated as a result of its absorption by tissues. With an equal thickness of the tissue layer through which they pass, photons are absorbed most strongly in bone tissue.

They are retained in parenchymal organs, muscles, and various media of the organism by half.

X-rays are absorbed less in fatty tissue and very little in the gases of the lungs, stomach, and intestines.

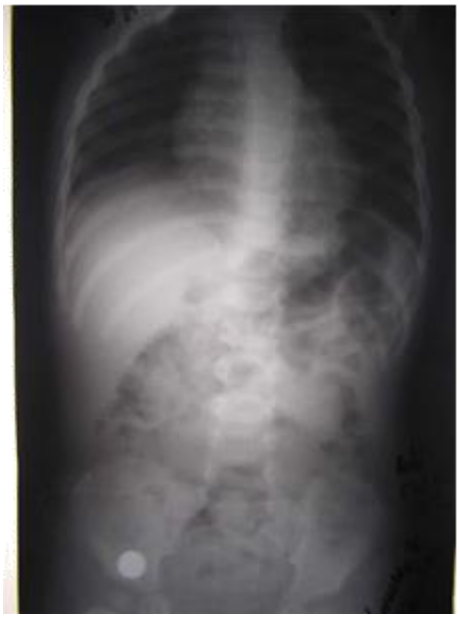
The more strongly the X-rays are absorbed in the examined tissue, the more intense the shadow it forms on the X-ray fluorescent screen during fluoroscopy, and the less its glow.

The image of the bones and heart on the fluorescent screen is black, the lungs is white. Such an image is called direct, positive.

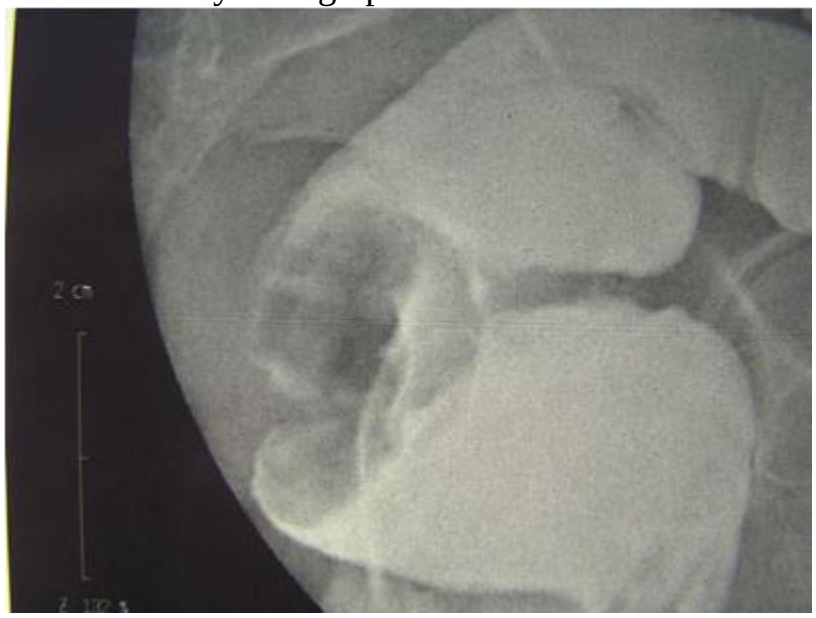
Radiographs, tomograms:

1. Survey - the entire anatomical region – head, chest, abdomen

2. Targeted - an image of a small part of the anatomical area that is of most interest to the doctor



Pic. 46. Survey radiograph of the chest and abdominal cavity

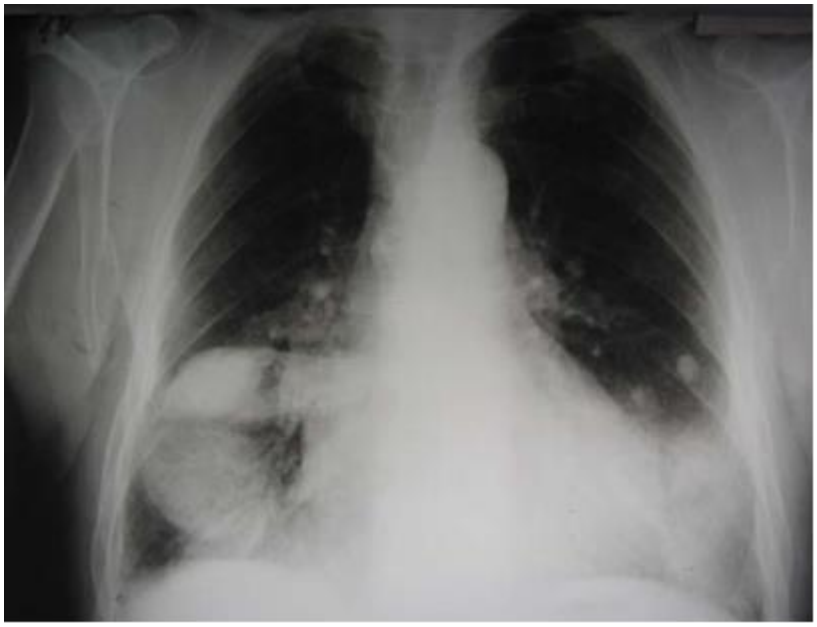


Pic. 47. Targeted radiograph of a part of the colon.

The resolving power of radiography is greater than that of fluoroscopy. During radiography, patients are exposed to significantly less radiation.

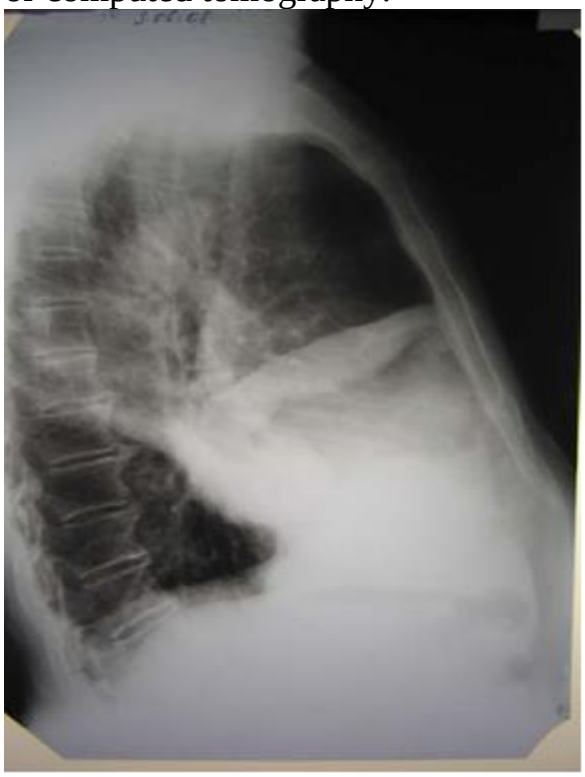
A flat negative image in black and white is formed on radiographs and computed tomography. When analyzing radiographs, it is necessary to take into account the presence of a summation effect. The summation effect in radiological diagnostics consists in superimposing images of some organs and tissues on others, which complicates the objective and qualitative diagnosis of pathological processes. In radiological diagnostics, there is a superimposition of various organs located along the path of the X-ray beam. For example, on a radiograph of the chest in direct

projection, due to the summation effect, the shadows of the spinal column, heart, large vessels and sternum are superimposed, and the image of the anterior segments of the ribs is sometimes superimposed on the image of the posterior ones. As a result, it is very difficult to accurately localize certain pathological changes.



Pic. 48. Radiograph of the chest cavity in a direct projection.

To avoid complications caused by the layering effect, radiographs are made in two mutually perpendicular projections (for example, radiography of the chest is performed in a direct and lateral projection) or tomographic techniques are used - linear or computed tomography.

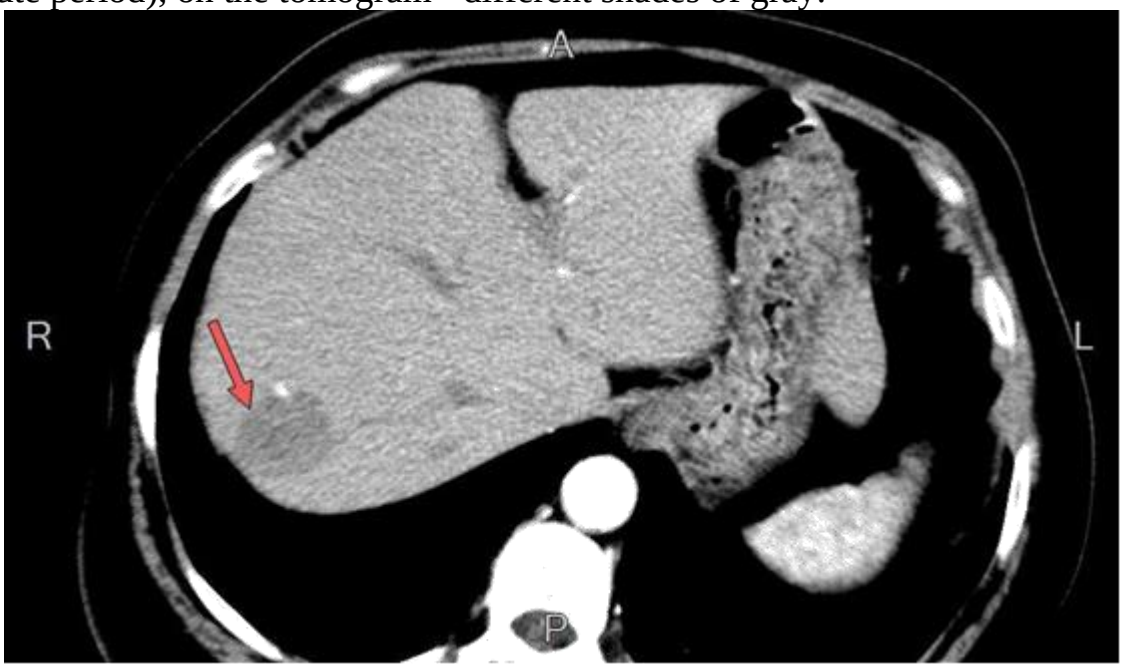


Pic. 49. Chest X-ray in lateral projection

Basic terms used in CT

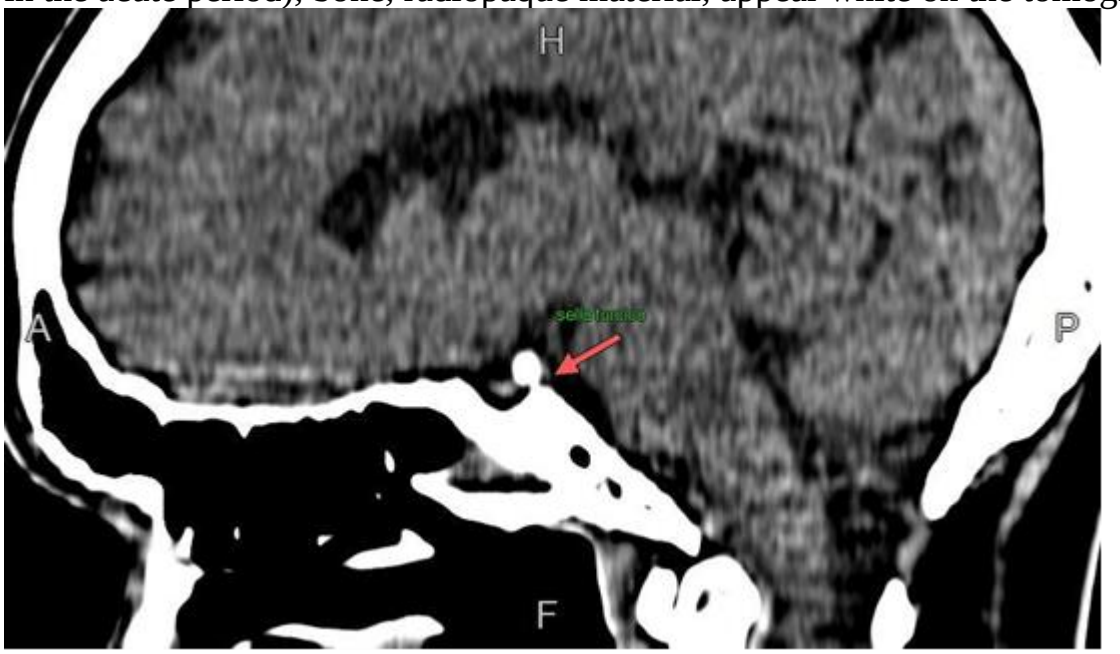
The following terms are used to characterize computed tomography images depending on the magnitude of the X-ray density of the detected morphological substrate:

• "isodense" - an image of the same density with surrounding tissues (formation of the same density with parenchymal organs, intracerebral hemorrhage in the subacute period), on the tomogram - different shades of gray.



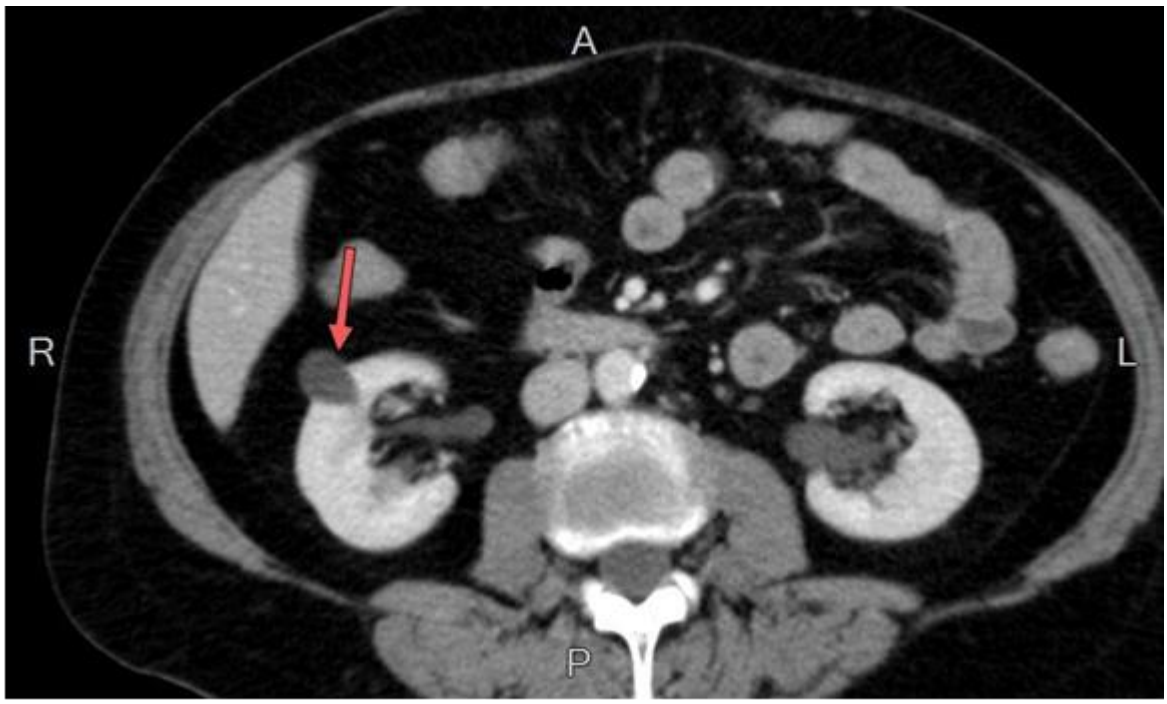
Pic. 50. A hypodense mass in the liver parenchyma with a lacunar accumulation of contrast material is caused by hemangioma.

• “hyperdense” - highly dense structures: blood (hemorrhage in the acute period), bone, radiopaque material, appear white on the tomogram.



Pic. 51. dorsum sellae

• “hypodense” - low-density structures - cerebrospinal fluid, gases, cystic fluid content, fluid as a manifestation of edema, have a black color on the tomogram.

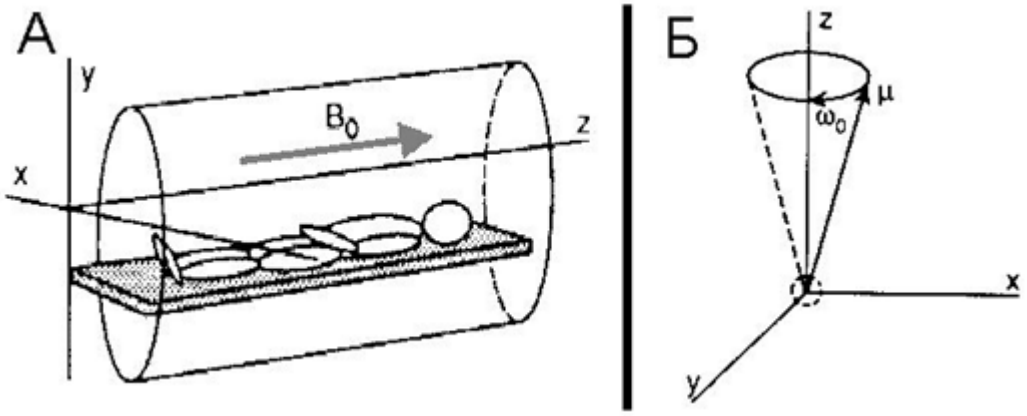


Pic. 52. Subcapsular cyst of the right kidney

MAGNETIC RESONANCE TOMOGRAPHY

Magnetic resonance tomography is one of the youngest methods of radiological diagnostics. MRI is a medical imaging method based on the physical phenomenon of nuclear magnetic resonance (NMR). After the inclusion of NMR in the number of medical tomography methods, the word "nuclear" was excluded from the association with radioactivity and radiation exposure during research, since in the mass consciousness it is associated with nuclear weapons or nuclear power plants, with which NMR has nothing in common, therefore, nowadays the term "magnetic resonance tomography" is used. MRI allows to obtain tomographic slices in different planes: axial, sagittal, frontal and others.

Physical foundations of MRI and the formation of MR images. MRI is based on the phenomenon of nuclear magnetic resonance. NMR is a physical phenomenon consisting in the ability of the nuclei of certain chemical elements, placed in a constant magnetic field, to absorb the energy of electromagnetic waves at a certain frequency, which is called resonant.



Pic. 53. Scheme of MR image formation.

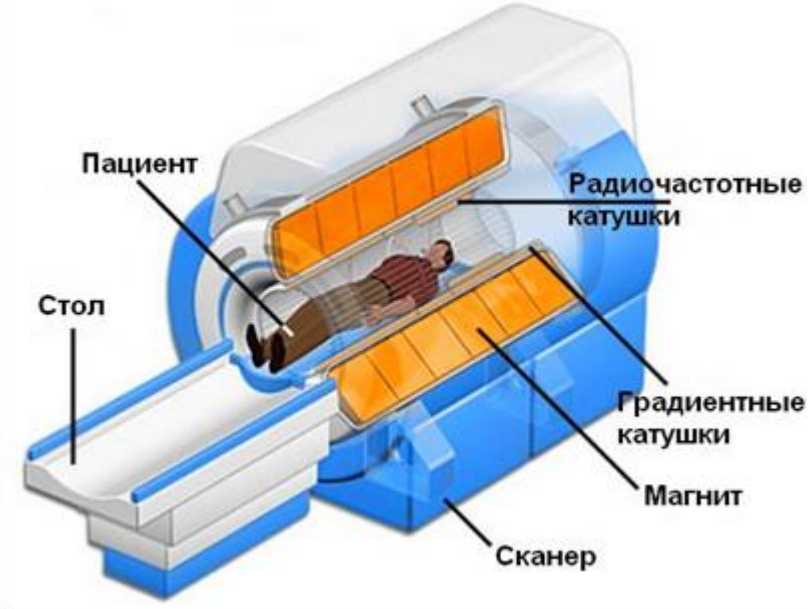
The main components of a magnetic resonance tomograph are:

• a ring-shaped magnet that creates a constant magnetic field of high intensity. This magnet is placed in a frame, in which, like a tunnel, the patient is placed during the examination

• a radiofrequency coil that generates and receives radiofrequency pulses;

• an information processing unit (computer).

• The human body is 4/5 composed of water and approximately 90% of the substance is hydrogen. In the center of the hydrogen atom is a proton, and on the periphery is an electron. The electron constantly rotates around the proton, but at the same time the proton rotates around its own axis, like a top, forming a cone. The frequency of rotation of the proton is directly proportional to the magnetic field strength and is called the Larmor frequency. The motion of a charged particle generates a magnetic field whose vector coincides with the direction of the cone of rotation, i.e. each proton can be represented as a small magnet, which has its own magnetic field and poles - north and south. Outside a strong magnetic field, these small magnets are oriented randomly.



Pic. 54. Scheme of a magnetic resonance tomograph.

When the patient's body is placed inside the magnetic field of an MP-tomograph, the magnetization of all protons is oriented parallel to the direction of the external magnetic field. In this case, a large part of the proton magnetization vectors is oriented in the same direction as the external magnetic field (i.e., towards "north"), and a smaller part is oriented in the opposite direction (towards "south"), so a total magnetic moment is created in the patient's body that coincides with the direction of the external magnetic field. Its value depends, first of all, on the proton density (proton density or PD) in various organs and tissues. However, the image of the organ under study is determined not only by the PD in it, but also by the chemical compounds in which hydrogen is found, therefore, for example, water and adipose

tissue, which contain a large amount of chemically bound hydrogen, generate different MR signals after the disappearance of the NMR.

The MP signal is a radio wave generated by protons after the disappearance of the NMR phenomenon for a certain period - the relaxation time. This radio wave is captured by a radio frequency coil, in which an electric current is induced, the amplitude of which is directly proportional to the intensity of the MR signal. But the MR signals emitted by protons of different tissues (for example, fluid formations and adipose tissue) also differ from each other in their duration. This is because during the relaxation process, chemically strongly bound protons (as in adipose tissue) give off energy emitted by radio waves much faster than less bound ones (as in water). Therefore, the relaxation time of water is much longer than that of fat.

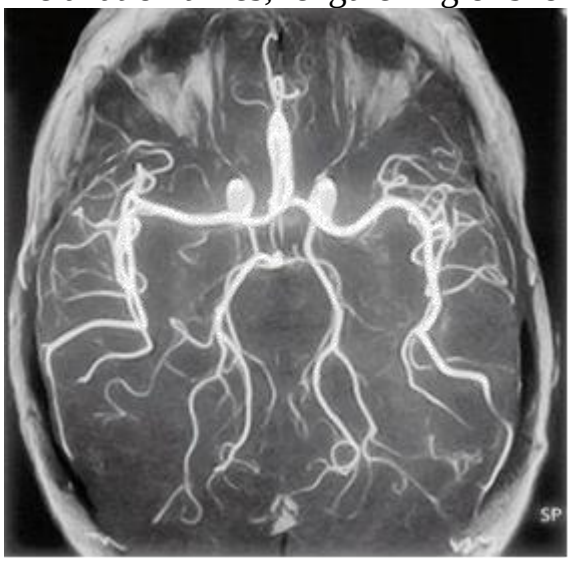
The relaxation phenomenon includes two processes that occur in parallel: the return of the magnetization vector created by the rotation of protons to the initial (before the occurrence of NMR) state; dephasing. Accordingly, the first process was called T1 relaxation, the second - T2 relaxation. The T1 relaxation time is the time required to reach 63% of the value of the proton magnetization vector that existed before the NMR phenomenon. The T2 relaxation time is the time required to reach a state when only 37% of the phase-synchronized protons from the initial value are preserved during the dephasing process. Accordingly, the intensity of the MP signal is affected by both PD and the T1 and T2 relaxation times of different organs and tissues. The MP signal obtained after a certain time after the disappearance of the NMR from organs and tissues that have different T1 and T2 relaxation times will differ in intensity.

Pic. 55. Magnetic resonance imaging.

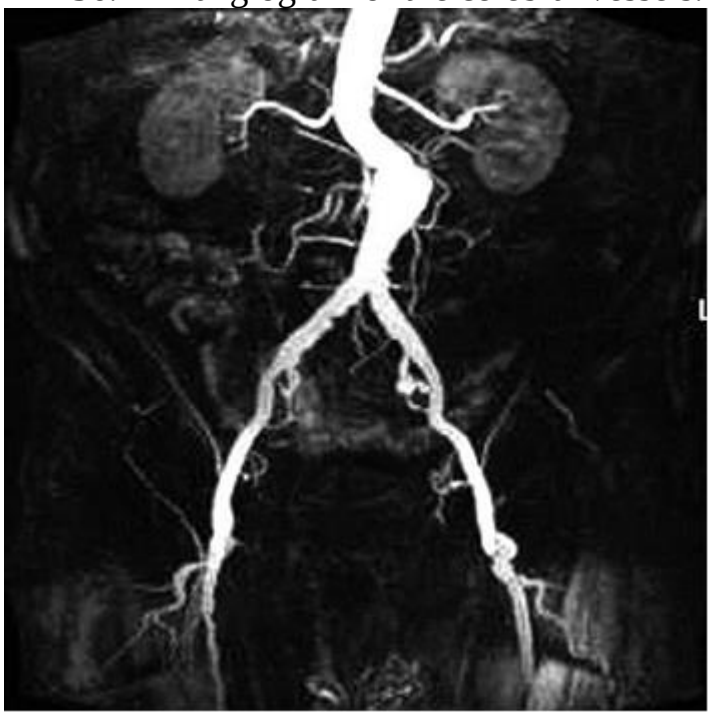
Magnetic resonance imaging with artificial contrast

MRI with artificial contrast. To improve the resolution of MPT studies, contrast enhancement techniques are used: substances that change the magnetic

properties of tissues are injected intravenously. MR contrast agents change the T1 and T2 relaxation times, lengthening or shortening them.



Pic. 56. MR angiogram of the cerebral vessels.



Pic. 57. MR angiogram of the abdominal aorta and its branches.

Groups of contrast agents for MRI:

•paramagnetics - gadolinium compounds, increase the intensity of the MP signal by reducing the T1 relaxation time, vascularized formations become hyperintense on T1-weighted images, when performing MR angiography, they improve the visualization of small arteries and veins.

•supermagnetics - iron compounds, reduce the intensity of the MP signal by shortening the T2 relaxation time, vascularized formations become hypointense on T2-weighted images.

Advantages and disadvantages of magnetic resonance imaging Advantages of MRI:

1. The absence of radiation exposure, which allows it to be used in different age groups and at different periods of a person's life, as well as to conduct multiple repeated studies if necessary to objectively monitor the course of the pathological process and the effectiveness of treatment.

2. Obtaining high-contrast images of soft tissue organs and structures in any plane.

3. Possibility of performing non-contrast angiography, urography, cholangiopancreatography, myelography.

4. Non-invasive determination of the content of various metabolites in vivo using hydrogen and phosphorus MR spectroscopy.

5. Possibility of performing functional studies of the brain for visualization of sensory and motor centers after their appropriate stimulation.

Contraindications to MRI:

Absolute: presence of metal and ferromagnetic structures in the patient's body (metal foreign bodies, pacemakers, implanted automatic drug dispensers, for example - insulin pumps, artificial heart valves, steel implants, artificial joints, metal osteosynthesis devices, hearing aids).

Relative: first trimester of pregnancy, claustrophobia, untreated convulsive syndrome, patient's motor activity.

Disadvantages of MRI:

1. High sensitivity to motor artifacts.

2. Limitations of the study in patients requiring hardware support of vital body functions (pacemakers, mechanical ventilation, implanted insulin pumps, etc.).

3. Poor visualization of bone structures due to low water content.

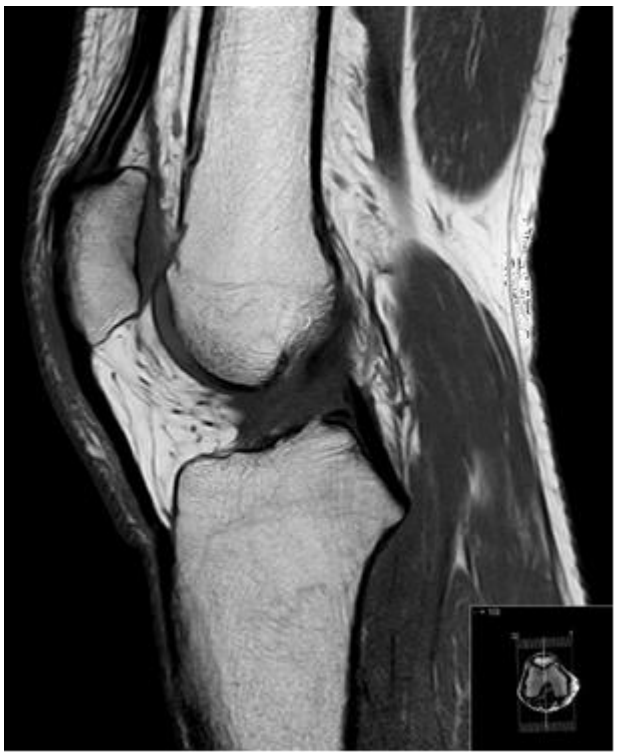
Indications for the use of this method are constantly expanding. If at first the main clinical application of MRI was limited to the clinic of neurological diseases, then at present studies are carried out on patients with diseases of the musculoskeletal system, heart and large vessels, pelvic organs, mammary glands, ENT organs, abdominal organs. Devices with a high magnetic field voltage, starting from 1.5 T, in addition to MRI perform spectroscopy programs, which allows studying the chemical composition of tissues and metabolic processes in vivo.

Basic terminology used in MRI

The following terms are used to characterize MP-tomograms: hyperintense and hypointense signal. The same morphological substrate appears hypointense on T1-weighted images and hyperintense on T2-weighted images.

• hypointense signal - compact bone, connective tissue structures, hemosiderin, fluid in T1WI, on the device screen or on the tomograms - black shades.

• hyperintense signal - fat, methemoglobin, fluid in T2WI, white shades on the device screen or on the tomograms.



Pic. 58. Knee joint, sagittal plane

RADIONUCLIDE TOMOGRAPHIC METHODS OF DIAGNOSTICS

Physical foundations of radionuclide diagnostics.

Radioactivity is the spontaneous transformation of atomic nuclei of unstable chemical elements into others, as a result of which certain types of ionizing radiation (corpuscular or electromagnetic) and energy are released.

Chemical elements that have atomic nuclei that are prone to spontaneous radioactive decay are called radionuclides. All radioactive radiation is ionizing, they are able to ionize atoms and decompose neutral molecules, including biological objects.

Physical properties of ionizing radiation

• high energy;

• high penetrating ability;

• ionizing ability - the ability to form many pairs of ions when interacting with atoms of the environment - used in dosimetry;

• photochemical ability - the ability to activate molecules of silver bromide or other chemical compounds (used in photodosimetry);

• luminescent ability - the ability to cause flashes of light in phosphors;

• thermal action - the ability of ionizing radiation energy to be converted into heat;

• strongly expressed biological action - used in radiation therapy.

Types of radiation

corpuscular:

ALPHA BETA

wave:

GAMMA

Alpha radiation - a stream of positively charged particles - helium nuclei containing two protons and two neutrons. It has the greatest ionizing and low penetrating ability. To protect against external influences, it is enough to protect yourself with any thin layer (for example, a sheet of thick paper). In addition, a person is protected from external alpha radiation by a natural impermeable barrier - the stratum corneum of the skin, consisting of dead cells of the epidermis.

Beta radiation is a stream of negatively charged particles - electrons or positively charged - positrons. It has a greater penetrating ability compared to alpha rays: the range in air is meters, in biological tissue - centimeters, therefore, to protect against them, denser and thicker screens are required (several millimeters of aluminum or several meters of air).

Gamma - radiation is hard electromagnetic oscillations that are formed during the decay of the nuclei of many radioactive elements. It has lower energy and the greatest penetrating ability, therefore, in modern radionuclide diagnostics, preparations that emit gamma quanta are used. The range in air reaches hundreds of meters, therefore, to shield against them, special devices made of materials that are able to well retain these rays (lead, concrete, water) are required. The ionizing effect of gamma radiation is mainly due to both the direct expenditure of its own energy and the ionizing effect of electrons ejected from the irradiated substance.

Basic principles of obtaining diagnostic information.

Radiopharmaceuticals

A radiopharmaceutical (RPP) is a chemical compound permitted for administration into the human body for diagnostic or therapeutic purposes, consisting of a pharmacological drug that reflects the metabolism of the organ under study and a radioactive nuclide that allows the distribution of the pharmaceutical drug in the organ under study to be traced.

All RFPs undergo certification similar to other drugs and pharmaceuticals. They must have appropriate chemical, radiochemical, and radionuclide purity and be sterile and non-pyrogenic. The chemical purity of a RFP is determined by the presence of other non-radioactive substances in it, especially heavy metal impurities. The radiochemical purity of a RFP is determined by the fraction of the radionuclide that is in the drug in the appropriate chemical form. Radiochemical impurities can significantly affect the reliability of the information obtained. Radionuclide purity of RFP is the absence of radionuclide impurities that can create undesirably high doses of radiation to the patient, reduce accuracy and change the results of the study. This type of purity is controlled by radio and spectrometry. Sterility is achieved by sterilization by one of 4 methods of steam treatment, dry heat, filtration, irradiation (radiation sterilization). Pyrogenicity is ensured by the use of pyrogenic reagents, solutions, dishes and compliance with relevant requirements in the process of production and preparation of drugs. The most important thing is that the drug provides useful diagnostic information, is harmless to patients and inexpensive.

Requirements for diagnostic RFP:

1) absence of chemical biotoxicity and radiotoxicity;

2) short half-life;

3) emission of gamma radiation (due to the greatest penetrating ability and the smallest bioeffect);

in the presence of biological properties that determine participation in the metabolism of the studied organ or system;

5) pharmacodynamics of RFP, in which it is quickly excreted from the body.

Routes of administration of RFP:

1. Enteral (per os): RFP is absorbed into the blood from the gastrointestinal tract and accumulates in the studied organ. For example, the absorption of radioactive iodine (inorganic stage of iodine metabolism in the body). When RFP is absorbed more slowly than it accumulates in the organ, then this route is limited. For example, we cannot determine kidney function with oral administration of RFP, because the kidneys remove this drug from the blood faster than it is absorbed in the intestine.

2. Intravenous administration of RFP: used to study the function and topography of the liver, kidneys, cardiovascular system, brain and other organs. The intraarterial route of administration of RFP is also used.

3. Subcutaneous: for indirect lymphography to assess the condition of lymph nodes in the diagnosis of regional metastases.

4. Intradermal: used to assess tissue resorption in vascular diseases.

5. Inhalation: to assess the ventilation capacity of the lungs and cerebral circulation.

6. Into lymphatic vessels: for direct lymphography.

7. Directly into the tissue: to assess muscle circulation.

8. Into the spinal canal: to determine its patency.

Radiopharmaceuticals are divided into:

Specific - with a certain selectivity of accumulation. Non-selective - without a certain selectivity of accumulation. Organotropic - selectively accumulating in a certain organ. Tumorotropic - selectively accumulating in a tumor (mainly malignant).

According to the ability to penetrate or not penetrate through hematotissue and membrane barriers:

- diffusing
- non-diffusing

Depending on the nature of accumulation in pathological foci, radiopharmaceuticals are divided into:

• Radiopharmaceuticals for positive visualization of pathological processes: there is a pathological appearance or increase in the intensity of gamma radiation over organs in which these radiopharmaceuticals do not normally accumulate (for example, phosphate complexes labeled with technetium (^{99m}Tc) are deposited in the area of myocardial infarction or labeled autologous leukocytes in the focus of inflammation).

• Radioactive tracers for negative visualization of pathological processes: these radioactive tracers normally actively accumulate in the organ under study, therefore the absence or decrease in their accumulation in this organ is regarded as a pathology (for example, when coronary blood flow is impaired, a zone of lack of accumulation

of ^{201}TI-chloride is formed on myocardial scintigrams, which normally actively accumulates in the myocardium due to intensive hemoperfusion.

By half-life:

- ultra-short-lived (half-life from minutes to hours);
- short-lived (half-life from hours to two weeks);
- long-lived (half-life more than two weeks).

The basis of radionuclide diagnostics is the measurement of radioactivity of the whole body or individual areas, i.e. organs, tissues and biological material that we take from the patient.

In this case, the following are studied:

1. Dilution of RFP. It occurs more often in liquid media of the human body. For example, using the dilution principle, the circulating blood volume (CBC) is measured. Serum albumin labeled with 99mTs-pertechnetate is injected intravenously, which circulates with the blood and does not go beyond the vascular bed. After mixing it (after 15-20 minutes), blood is taken and the radioactivity is measured in a well counter, which is compared with the radioactivity of the injected RFP. The larger the volume of circulating blood, the lower the concentration of RFP in it. CBC is calculated using the dilution formula:

2. Movement speed. For example, determining the speed of venous blood circulation of the lower extremities. For this purpose, RFP is injected into the vein of the foot, the detector is installed in the area of the Pupart ligament, the recorder is turned on, which records the chronogram. The time of the appearance of the rise in activity on the curve will be a measure of the blood circulation rate (sec).

3. Accumulation and excretion. If we inject a drug tropic to the organ, then the better the blood circulation in it, the better the organ functions, the faster it will capture this drug from the blood. The radioactivity of the drug will decrease, and the faster it will be excreted from the body if it is excreted, for example, by the kidneys. In other cases, when the drug, for example, a labeled colloid, is not excreted by the liver, the excretion phase will be absent. Therefore, on the recorder, the rise of the curve will be high and steep. If the organ function is reduced, then this rise will be low and gentle, and the dose excretion will be slow, accordingly, the precardiac radioactivity curve (blood clearance curve) also decreases more slowly. The obtained parameters can be calculated in relative or absolute values, which is determined by mathematical modeling of physiological processes and makes it possible to study the function of the organ

4. Distribution of radiotracers. This principle makes it possible to obtain a gamma topogram (scanogram, static scintigram, emission tomogram) using an organotropic preparation, to study the topography of the organ (location, size, shape, contours), to detect focal and diffuse pathological changes due to the uneven distribution of radiotracers in it

5. Interaction. The principle is used more often in in vitro diagnostics, which is based on the interaction (competitive combination) of the desired stable and similar labeled compounds (antigens) with a specific receptor system - with an antibody. For this, commercial kits are used, which include: a radioactive antigen (analog of the one

that needs to be determined), 5 test tubes with standard known concentrations to obtain a calibration curve. These components are added to a test tube to which the patient's blood serum is added. The antibody is taken in less quantity than the total number of antigens competing for binding to the antibodies. In this case, the advantage will be on the side of the antigen that is more abundant. After incubation, we centrifuge and conduct radiometry of the bound complexes that have precipitated. If the antigen content in the blood serum is high, the precipitate will be less radioactive. And if there is little antigen in the serum, then more radioactive thyroxine will bind to the antibodies and the precipitate will be more radioactive, for example, for the quantitative determination of thyroxine, the same study is carried out with standard concentrations of non-radioactive antigen, for example, 30, 60, 90, 120, 150 nmol/l of thyroxine. According to the results of radiometry, we draw a graph of the dependence of radioactivity on concentration, that is, a calibration curve is obtained. From the value of radioactivity on the ordinate axis, we draw a horizontal line to the intersection with the calibration curve, lower the perpendicular to the abscissa line and take the indicator of the concentration of thyroxine in the patient's blood. When equipped with a multi-channel counter (for example, a 12-channel Gamma-800), the computer calculates the results of radioimmunological analysis (RIA) and prints them out automatically. Antibodies may be detected. In this case, the reaction is called immunoradiometric analysis (IRMA).

Stages of the study:

1. Parenteral administration of RFP.
2. Entering the human body, RFP is included in physiological or pathophysiological processes, which, in turn, is determined by local blood flow and the activity of metabolic processes.
3. Selective absorption of RFP by organs in the metabolism of which this RFP is involved.
4. In this case, the organ under study must be at least minimally functionally active. A non-functioning organ does not accumulate RFP! Absorption of RFP makes it possible to obtain diagnostic information about the morphological and functional state of the organ or biological system under study.
5. Registration of gamma radiation in an organ with selective accumulation of RFP.

Gamma quanta emitted by radioactive nuclides in the patient's body propagate rectilinearly in all directions, transfer energy, as a result of which glow - scintillation occurs. Gamma quanta are captured by special detectors located near the patient's body. Registration of pathological processes is based on measuring the level of radioactivity above the organ under study in relation to the surrounding tissues.

Types of radionuclide tomographic studies

Types of radionuclide studies:

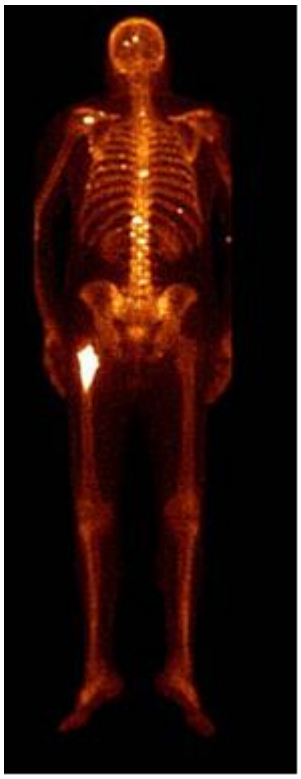
Dynamic:

to study the dynamics of the distribution of radionuclides in the organ.

Static:

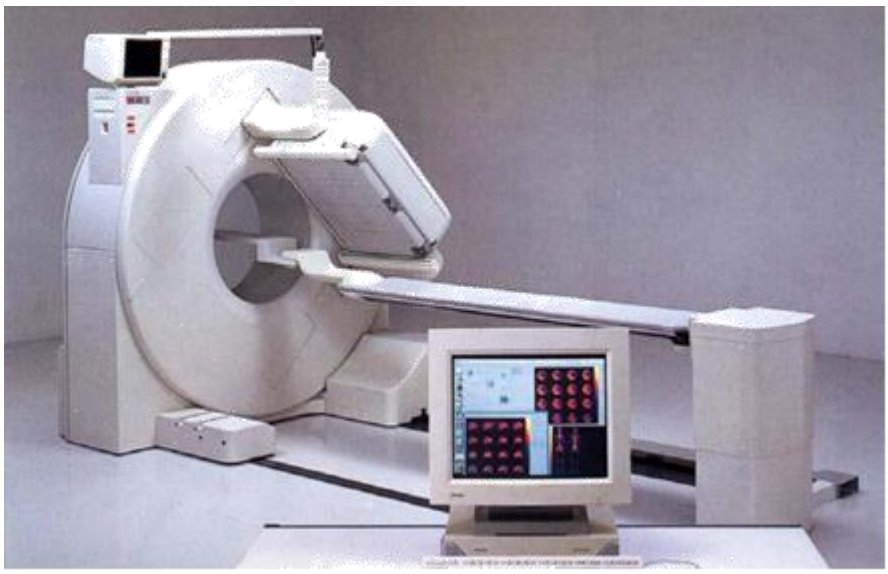
to assess the spatial distribution of radionuclides in the patient's body or organ.

Static studies: the degree of accumulation of radionuclides in tissues is calculated, the indicators of the degree of accumulation in different parts of the organs are compared, the uniformity of accumulation within the organ is assessed.
Dynamic studies: the change in the level of radioactivity above the organ under study is studied with the subsequent construction of radionuclides distribution curves depending on time (from the moment of intravenous injection of radionuclides for a certain time). Used in the study of organ function: kidneys, liver, biliary tract, thyroid gland. **Scintigraphy is** a method of radionuclide diagnostics that provides images of organs and tissues by registering radiation on a gamma camera emitted by an incorporated radionuclide. It provides information about the topographic and anatomical characteristics and the nature of the distribution of radionuclides in the studied biological object.
Planar scintigraphy - images of organs and tissues are obtained in a certain plane. The main disadvantage of planar scintigraphy is the summation effect.
The use of tomography techniques in radionuclide diagnostics has eliminated the summation effect.



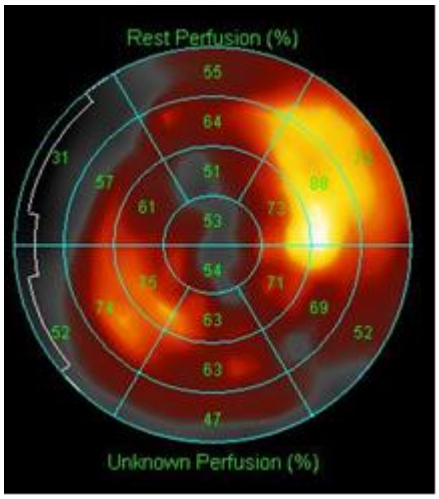
Pic. 59. Static skeletal scintigram.

Emission tomography allows for layer-by-layer imaging.



Pic. 60. Emission tomography.

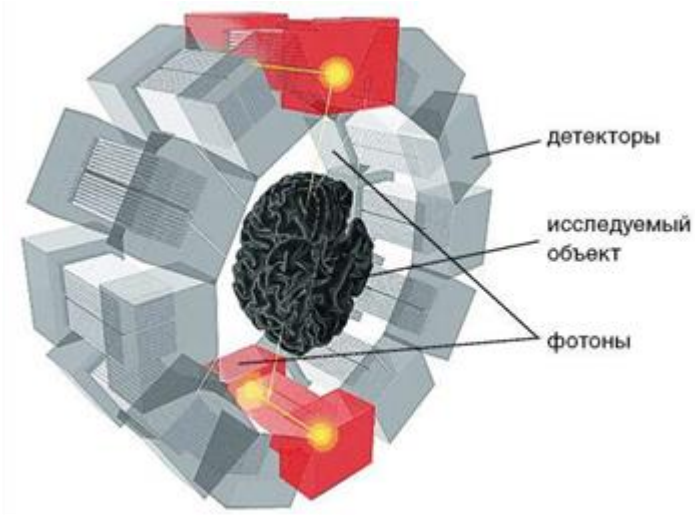
Single-photon emission computed tomography (SECT). This technique allows obtaining images of axial slices of the examined organ due to the rotation of the gamma camera detector around the examined object. In this way, the summation effect is eliminated.



Pic. 61. Axial slice.

If necessary, axial slices are reconstructed into images in other planes. Another advantage of OECT, compared to planar scintigraphy, is high resolution, that is, there is the possibility of a more detailed study of the features of the organ under study.

Positron emission tomography (PET) is a technique that involves the introduction of radionuclides that emit radiation, or positrons, into the human body. Each emitted radionuclides-positron begins to interact with the nearest electron in the human body. Positrons and electrons have the same mass, but opposite electric charges, so their mutual destruction occurs - annihilation. During annihilation, annihilation gamma quanta are released, which propagate in opposite directions and are captured by special detectors.



Pic. 62. PET scheme.

PET allows for an accurate quantitative assessment of the concentration of radionuclides in the organ under study and can be used for a detailed study of the metabolic processes occurring in it. For example, PET is relevant in the diagnosis of malignant tumors: in tumor cells with a high level of carbohydrate metabolism, which are actively metabolized, ^{18}F-deoxyglucose (a metabolic analogue of regular glucose) accumulates very intensively. PET is also actively used in cardiology: ^{18}F-deoxyglucose is well included in the carbohydrate metabolism of the myocardium and allows you to determine the degree of its viability.

Directions and advantages of using radionuclide studies

Currently, the main directions of using radionuclide studies are:

1. Diagnosis of malignant tumors and search for metastases (especially small ones, in the initial stages of their development).
2. Study of the functional state of various organs.
3. Search for foci of infection in fever of unknown origin (advantage - the possibility of studying the whole body).
4. Diagnosis of regional blood flow disorders: detection of latent ischemia, assessment of the area of myocardial damage, assessment of myocardial viability, diagnosis of the initial stages of stroke (first hours), transient ischemic attacks.

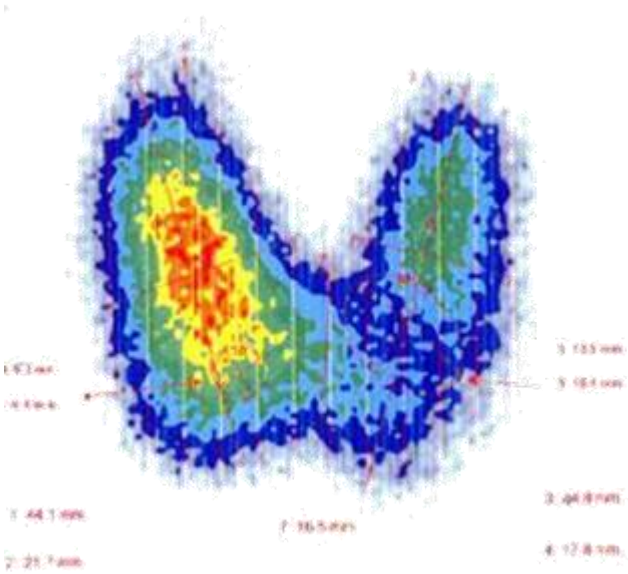
Advantages of radionuclide diagnostics.

The basis of the X-ray method, CT, ultrasound, MRI is visualization of the morphological characteristics of the organ or system under study.

The main advantage of radionuclide methods in comparison with other means of radiation diagnostics is the ability to obtain diagnostic information about the functional state of the studied organ or biological system. Another important advantage is the ability to simultaneously examine the entire body (for example, visualization of all metastases of a certain tumor in all organs and systems).

Key terms used in radionuclide diagnostics:

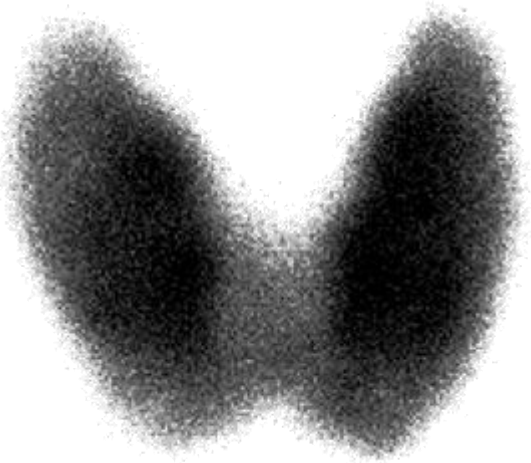
A scintigraphic image can be presented in both black and white and color modes.



Pic. 63. On the scintigram, there is a uniform accumulation of RFP by the thyroid gland.

When evaluating the obtained scintigraphic images, terms are used that characterize the degree of accumulation of the tracer.

• “hot” focus - a zone of increased accumulation of RFP, hyperfixation of RFP in the studied area (for example, increased inclusion of osteotropic RFP in a bone neoplasm);



Pic. 64. On the scintigram, a hot focus of the right lobe of the thyroid gland.

• “cold” focus - a zone of reduced accumulation, hypofixation of radiopharmaceuticals in the studied area (for example, a zone of no accumulation of radiopharmaceuticals in the area of a thyroid cyst).

Pic. 65. On the scintigram, a cold focus of the left lobe of the thyroid gland.

TOPIC 4. ULTRASOUND DIAGNOSTICS

Ultrasound diagnostics is a diagnostic method that is excellent for visualizing the condition of internal organs, blood flow and blood vessel patency. Ultrasound is a minimally invasive method of examining internal organs, which is based on the ability of sound waves to reflect off various structures of the body. This method of examination is the main one in modern medical practice. The procedure for performing ultrasound requires special training and depends on which organ needs to be examined.

PREPARATION FOR ULTRASOUND OF THE ABDOMINAL ORGANS

This type of examination allows the doctor to obtain a comprehensive assessment of the health of the abdominal organs. Preparation for an ultrasound of the abdominal cavity is, first of all, a diet that allows you to eliminate bloating and increased gas formation - factors that can interfere with the study, the results will be unreliable. Recommendations for preparation:

• the day before the examination, exclude such products as: milk, cabbage, black bread, legumes, fresh vegetables and fruits, sweet dishes, carbonated drinks;
• take a sorbent (dosage as prescribed by the doctor);
• come to the examination on an empty stomach: do not drink anything, do not eat, do not take medications;
• if an ultrasound examination of the abdominal organs with a water-siphon test is prescribed, then you need to drink 200 ml of water;
• if an ultrasound examination of the abdominal cavity organs with determination of gallbladder function is prescribed, then it is necessary to take a choleretic breakfast (chocolate, banana or sweet tea).

PREPARATION FOR ULTRASOUND OF THE KIDNEYS AND URINARY BLADDER

The kidneys, adrenal glands and urinary bladder are the main organs of the urinary system, which are most prone to the formation of stones, polyps, cysts and other pathological formations that can be detected by ultrasound. Recommendations for preparation:

• the day before the examination, exclude such products as: milk, cabbage, black bread, legumes, fresh vegetables and fruits, sweet dishes, carbonated drinks;
• take a sorbent (dosage as prescribed by the doctor);
• come to the examination with a full bladder;
• 1 hour before the examination, you need to drink 500 ml of water.

PREPARATION FOR ULTRASOUND OF THE PELVIC PANTRY (TRANSABDOMINAL)

Ultrasound examination of the pelvic organs allows to determine the condition of the bladder, ovaries, uterus, cervix and fallopian tubes in women, and in men - the condition of the prostate gland.

Indications for performing an ultrasound of the pelvis may be pain in the groin area, detection of blood in the urine, problems with urination, infertility, menstrual cycle disorders in women, decreased potency in men. Recommendations for preparation:

• the examination is carried out on the 5-10th day of the menstrual cycle (the 1st day is the beginning of menstruation);
• the day before the examination, exclude such products as: milk, cabbage, black bread, legumes, fresh vegetables and fruits, sweet dishes, carbonated drinks;
• take a sorbent (dosage as prescribed by the doctor);
• come to the examination with a full bladder (you need to drink 500ml of water or juice 1 hour before the examination).

PREPARATION FOR ULTRASOUND OF THE BREAST GLANDS

There is no special preparation for the examination. The only condition for obtaining the most accurate results is the choice of the day of the ultrasound. As practice shows, it is best to conduct an ultrasound examination in the first half of the cycle, that is, before ovulation. With a cycle duration of up to 28 days, an ultrasound of the breast glands is best done in the period from 5 to 10 days. If the cycle is longer, then from 7 to 14. Sometimes before the diagnosis, the doctor may cancel the intake of hormonal drugs and suggest when it is better to do an ultrasound of the breast glands in this case.

During menopause, pregnancy and breastfeeding, the examination can be performed on any day. If chest pain occurs with an increase in general temperature, the examination is prescribed on an emergency basis.

Do not require special preparation:

• Ultrasound of the heart;
• Ultrasound of the thyroid gland;
• Ultrasound of the scrotum;
• Ultrasound of the joints;
• Ultrasound of soft tissues;
• Ultrasound of the thymus gland;

• Ultrasound of peripheral lymph nodes.

Pic. 66. Ultrasound dopplerography of vessels.

ULTRASOUND DOPPLEROGRAPHY OF VESSELS

Ultrasound Dopplerography is one of the modern types of research into the functioning of blood vessels in the body. It is performed using an ultrasonic sensor that measures the speed of blood flow in the vessels of the neck and head, lower extremities, abdominal aorta and other parts of the body. If the patient has any abnormality, doctors record it and prescribe treatment. Ultrasound Dopplerography is also performed with color coding of blood flows. The use of color helps to conduct a more thorough examination. In this case, the blood flow going to the sensor is coded in red, and from the sensor - in blue. Dark shades of these colors correspond to low speeds, light ones - high.

Indications for color-coded ultrasound Dopplerography:

• headaches and frequent loss of consciousness for no reason
• “flies” before the eyes
• balance disorders and dizziness
• blindness in one eye
• swelling and heaviness in the legs
• loss of sensitivity and numbness in the legs
• trophic ulcers
• intermittent claudication
• varicose veins
• atherosclerosis and endarteritis

Methods of performance

• the procedure does not require special preparation, however, certain recommendations may be prescribed by the doctor
• the procedure is performed in a lying position on a couch
• the patient exposes the area to be examined, and the doctor applies a special gel to the skin and performs a scan
• ultrasound Dopplerography is absolutely safe and painless

• the procedure lasts an average of 20-60 minutes
• the results of the Dopplerography are deciphered by the doctor

NEUROSONOGRAPHY

Neurosonography is an ultrasound examination of the baby's brain.

The procedure is planned, as is a visit to a specialist in a clinic, and is mandatory for all babies aged 1-3 months, even without any neurological abnormalities or obvious signs of the disease.

It is during this period, when the fontanel has not yet closed, that it is possible to best examine the structure of the brain and detect:

• congenital developmental anomalies;
• cysts;
• hemorrhages;
• consequences of previous edema;
• dilation of the cerebrospinal fluid;
• tumors.

This diagnostic method is effective for tracking the dynamics of a child's development and progress in treatment.

Symptoms that require ultrasound in children:

• asymmetric, non-standard or irregular head shape, disproportionate size;
• lag in psychomotor development;
• frequent crying for no reason;
• hyperexcitability;
• protrusion or depression of the fontanel.

There are no contraindications for brain ultrasound in children.

What does a child's brain ultrasound show?

Neurosonography can detect a number of brain and CNS diseases.

Diseases:

• Brain ischemia
• Brain tumors
• Meningitis
• Brain cysts
• Cerebral palsy
• Hydrocephalus
• Down syndrome
• Apert syndrome
• Aneurysms and internal hemorrhages in the brain
• Genetic disorders

A neurosonogram describes various brain structures (gyri and sulci, cerebellar tent, cerebellar structures), the symmetry of the ventricles, the state of vascular bundles, etc.

Preparation

Neurosonography does not require special preparation for the study. Before the ultrasound, the child should be fed and given a drink. It is advisable that the baby

sleeps during the examination, which will ensure a calm and motionless state of the child.

How is neurosonography performed?

It is very easy to do neurosonography. During the examination, the baby is in the arms of the parents or lies on the couch (this position is most convenient if the child is sleeping).

The doctor conducts the examination using a special ultrasound sensor through the large fontanel, on which a hypoallergenic gel is applied for better contact with the skin. Additionally, the large parietal foramen and additional fontanels near the child's ears may be involved in the diagnosis.

The entire examination, as a rule, takes no more than 15 minutes.

ULTRASOUND OF THE ABDOMINAL CAVITY AND PYLORIC DEPARTMENT OF THE STOMACH OF A CHILD

Ultrasound of the abdominal cavity and pyloric region of the stomach is usually prescribed to a child by a pediatrician after a routine examination. Do not be afraid of ultrasound diagnostics: it is a safe, accurate and informative method of examination, it can be performed on children from the first day of birth and as many times as necessary.

During the procedure, the doctor examines the condition of the liver, gallbladder, pancreas, spleen and pyloric region of the stomach. He assesses the size, location of the organs and the structure of the tissues, can see congenital structural pathologies, neoplasms and signs of inflammatory diseases. The value of ultrasound lies in the early diagnosis of diseases - and early diagnosis is an important prerequisite for recovery.

In what cases can an ultrasound of the abdominal cavity and pyloric region of the stomach be prescribed to a child?

If the pediatrician, after listening to the complaints of the mother and baby, suspects a violation of the functioning of the abdominal organs, he may prescribe an ultrasound scan to clarify the diagnosis. Such a study is performed for infants for screening purposes - to exclude or detect congenital malformations in a timely manner.

Other reasons for prescribing an ultrasound scan may be:

- "fountain" vomiting in newborns (ultrasound will help exclude or diagnose pyloric stenosis),
- digestive disorders, frequent loose stools, bloating, constipation,
- low body weight, insufficient weight gain,
- infection of the abdominal organs,
- pain in any part of the abdomen,
- trauma to the abdomen or hypochondrium.

Pic.67. Ultrasound of a child.

How to prepare your child for the procedure

Stomach and gallbladder ultrasound is performed on an empty stomach, so it is better to schedule the procedure for the morning. The exception is infants who are undergoing ultrasound for screening purposes, in which case abstinence from food is not required.

Do not feed your child before an abdominal ultrasound:

• 8-10 hours if the child is older than 7 years old,

• 6 hours for children from 1 to 6 years old,

• 2-4 hours for infants if there are suspicions of disorders in the functioning of the abdominal organs.

Excessive gas formation in the intestine also prevents obtaining an objective picture, so before the ultrasound you need to follow a special menu.

1-3 days before the ultrasound, you need to exclude from your diet:

• white bread, sweets,

• carbonated drinks,

• sauerkraut,

• milk,

• legumes, etc.

In case of pathological changes, it is necessary to focus on a specific area that requires changing the parameters of the ultrasound scan. All this justifies the need to use the expert-class TOSHIBA APLIO 400 devices in pediatrics. The speed of operation, high image quality, and ease of changing the scan parameters make it possible to effectively and comfortably conduct examinations on babies.

TOPIC 5. FUNCTIONAL DIAGNOSTICS

Functional diagnostics is a set of methods for studying the human body to determine the activity of individual organs, systems or the human body as a whole, objectively assess their function, identify pathology and determine the degree of functional disorders.

Tasks of functional diagnostics

Functional diagnostics is a section of medicine that deals with objective assessment, identification of pathologies, and determination of their degree within the framework of the study of various organs and systems of the body. Instrumental and laboratory methods can be used to perform research.

Pic. 68. ECG.

The purpose of any diagnosis is determined by the following clinical tasks:

• detection of abnormalities in the functioning of one or more organs;

• characterization of the functioning of the physiological systems of the body;

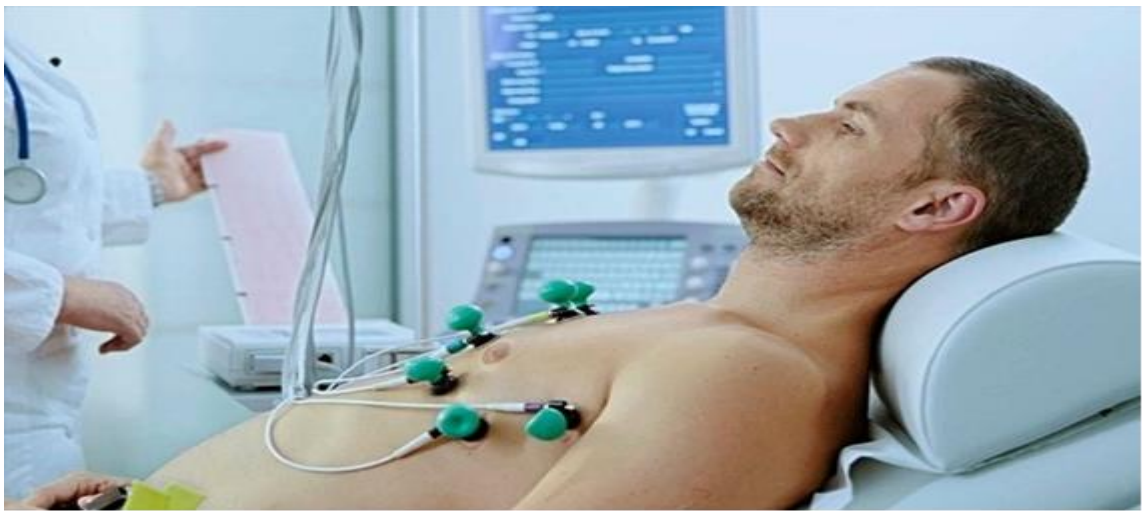
• study of the progression of pathology and its impact on other organs;

• assessment of the reserve of functional capabilities of the organ;

Functional diagnostics is a set of methods for studying the human body, which are designed to determine the activity (functioning) of individual organs, systems or the human body as a whole.

Methods of functional diagnostics are ECG, Holter ECG, PH metry and PH monitoring, spirography, etc.

Functional diagnostics allows you to detect abnormalities, objectively evaluate them and determine the level of dysfunction of various organs and physiological systems of the body based on the results of measuring a number of indicators. Modern computer equipment allows you to carry out such diagnostics at the highest level: it performs automatic information processing, determines a wide range of indicators and forms a graphic image of the results obtained. The advantage of functional diagnostics is that it is simple to perform and has no contraindications for any patient.



Pic. 69. Electrocardiography.

ELECTROCARDIOGRAPHY

ECG as a method of assessing cardiac activity first appeared in 1903, but in practical healthcare, for the purpose of diagnosing heart pathology and to facilitate diagnosis, it took its place in the early 50s of the last century. Actually, it serves this purpose even today, fully satisfying both clinical medicine and the patient.

This method is one of the main ones in diagnosing cardiac pathology. The electrocardiograph registers and records on paper or electronic media the indicators of cardiac electrical activity. Thanks to this, a functional diagnostician can, during the decoding of the information received, identify many health problems in the patient.

Including any conduction and rhythm disorders are detected. A specialist can assess how well the myocardium is coping with its functions, diagnose various ischemic changes even at the earliest stage of development, including such a formidable pathology as myocardial infarction.

The procedure for taking an electrocardiogram does not pose any danger to the patient's health and is completely painless. It is performed by a functional diagnostics nurse. Modern equipment that records an ECG, in addition to conducting the study itself, is able to accumulate a huge amount of data in its memory, and also, on their basis, to control the quality of the treatment courses completed by patients.

However, the heart beats in the chest not only of a sick person, but also of a healthy person, and electrocardiography can provide answers to questions that are relevant to him:

o whether he has signs of initial deviations from the norm;

o is there a risk of developing cardiac pathologies;

o what are the individual capabilities of the patient's heart to perform various life stresses;

An **ECG** is indispensable in the diagnosis of electrolyte metabolism disorders that occur under the influence of various toxic substances.

An **ECG** is widely used for functional research of the cardiovascular system. The combination of electrocardiographic examination with functional tests helps to detect latent coronary insufficiency, transient rhythm disturbances, and to conduct a differential diagnosis between functional and organic heart disorders.

HOLTER ECG

Holter (ambulatory, 24-hour) ECG monitoring is a long-term ECG recording in the patient's daily activity with subsequent analysis of the resulting recording. It makes it possible to detect heart abnormalities, even if they occur very rarely, since the ECG recording is carried out continuously for 1, 2, and if necessary, up to 7 days.

The method is named after the American researcher Norman Holter, who introduced radioelectrocardiography and was the first to perform long-term ECG recording.

This method is non-invasive and highly informative, it is widely used both in stationary and outpatient settings for the diagnosis of ischemic heart disease (IHD), heart rhythm and conduction disorders, as well as for assessing the effectiveness of treatment of cardiovascular diseases.

Holter ECG monitoring (HEM-ECG) is one of the best methods for diagnosing and assessing the effectiveness of treatment of cardiovascular diseases. The main indications for the use of this examination method are analyzed in detail, in particular, the assessment of symptoms that may be associated with heart rhythm and conduction disorders; risk stratification in patients with structural heart diseases without symptoms of arrhythmia; assessment of the effectiveness of treatment of cardiac arrhythmias; assessment of the function of implanted devices; diagnosis and assessment of the effectiveness of treatment of myocardial ischemia.

The examination procedure is very simple: using special electrodes, a small device is connected to the patient, which is fixed on the belt. The patient leads a normal lifestyle. All that is needed is to keep a diary in which the patient notes the features of his well-being, complaints, type of activity, taking medications, physical activity, sleep and wakefulness time.

After a specified time, the data from the device is decoded on a computer.

The data processing program is able to detect and analyze all types of arrhythmias and angina attacks. In addition, the doctor himself reviews the record and can correct program errors. This method helps not only to make a diagnosis with sufficient accuracy, but also to increase the effectiveness of cardiovascular disease treatment many times over.

Who is prescribed this procedure?

Indications for Holter monitoring are the following situations:

• early detection of myocardial ischemia - in men over 35 years of age and women over 40 years of age, it is performed once every three years, in cardiology patients - once a year;

• monitoring of antiarrhythmic therapy;

• monitoring of antiischemic therapy (before treatment and three weeks after it);

• with concomitant syndromes and conditions (thyroid diseases, thyrotoxicosis; high cholesterol; planned pregnancy);

• during pregnancy at any stage (once).

The method is also indicated for:

• loss of consciousness and fainting;
• increased blood glucose (painless myocardial ischemia is searched for);
• anemia of any origin;
• shortness of breath;
• chest pain;
• third-degree obesity;
• planned surgery for sleep apnea;
• chronic fatigue syndrome, as well as before and after radiation or chemotherapy.

The method is indicated for people in hazardous professions (every year): pilots, public transport drivers, divers, crane operators, industrial climbers, air traffic controllers.

DAILY BLOOD PRESSURE MONITORING

There are many situations when the results of blood pressure measurements in the doctor's office are far from the objective real values. This can be explained by the reaction of the cardiovascular system to a visit to the doctor, when "white coat" hypertension occurs. There are also other situations when one-time blood pressure measurements and medical history data do not provide sufficient information about blood pressure fluctuations, and normal blood pressure readings obtained during the examination do not give confidence that they are real. In fact, for a more accurate diagnosis of blood pressure, the method of daily blood pressure monitoring is used.

A device for daily blood pressure monitoring provides regular, 24-hour blood pressure measurement at specified intervals and storage of results on a special medium. The information obtained is processed by a computer program, and the results are given to the patient in printed form.

The World Health Organization indicates the following advantages of using DMAT:

• DMAT data more accurately reflect the level of blood pressure in the conditions of the patient's usual life;
• mean BP values obtained with DMAT are more closely related to target organ damage than clinical measurement data;
• DMAT data before the start of treatment may have prognostic value in the development of cardiovascular complications;
• regression of target organ damage is more closely related to changes in average daily BP values than to the level of clinical BP;
• assessment of BP levels and fluctuations over 24 hours (some patients are characterized by nocturnal and morning BP increases, which is especially dangerous given the risk of stroke or heart attack);
• diagnosis of "white coat" hypertension;
• more accurate assessment of the severity of arterial hypertension;
• better selection of medications and assessment of the duration of the effect in each specific case.

To obtain correct results of daily blood pressure monitoring, it is necessary to adhere to the following rules:

• lead a normal lifestyle during the study;

• at the time of blood pressure measurement, the arm with the cuff should be as relaxed as possible;

• keep a detailed diary of events with a clear record of time, indicating the period of sleep, physical activity, taking medications, etc.;

• handle the device carefully, avoid mechanical damage, and ensure that the rubber hose through which air is supplied is not pinched.

CAT — CENTRAL AORTIC PRESSURE MEASUREMENT

Central aortic pressure measurement is a new non-invasive method of measuring blood pressure in the aorta, the largest and most important vessel in the human body.

How does central aortic pressure differ from normal blood pressure?

Central aortic pressure measurement shows the pressure level in the aortic root, the largest vessel that originates directly from the heart. Central aortic pressure is not the same as the pressure in peripheral vessels. Normally, in healthy people, the pressure in the aorta is lower than in the peripheral arteries. In some situations (aging, hypertension, high blood cholesterol, smoking, diabetes), the central aortic pressure becomes higher than the pressure in the brachial artery. The importance of determining the central aortic pressure is also due to the fact that antihypertensive drugs that doctors prescribe to patients with hypertension act differently on different vessels, so they can well reduce the level of A/T in the shoulder, but at the same time increase the level of A/T in the aortic lumen.

Why is it important to measure the central aortic pressure?

Central aortic pressure directly affects the heart, brain and kidneys, so its increase indicates damage to these vital organs. The main reason for the increase in central aortic pressure is the increase in vascular stiffness, when they lose their elasticity and compliance. The consequence of increased vascular stiffness is an increased speed of propagation of the pulse wave through the vessels.

Why is it important to measure the speed of propagation of the pulse wave through the vessels?

The speed of propagation of the pulse wave (SPWP) through the vessels is the main indicator of their elastic properties. Its increase is an important sign of the loss of normal elasticity of the arteries. It has been proven that, regardless of the presence of other risk factors, cardiovascular diseases (myocardial infarctions, strokes) occur more often in people with increased SPWP.

Who should measure central aortic pressure and SPWP?

In people with high blood pressure and those who are in the cardiovascular risk group (increased blood cholesterol, smoking, diabetes, hereditary predisposition to cardiovascular diseases). As well as patients who take medications to lower blood pressure, in order to accurately select the type and dose of drugs.

Healthy people of any age, to determine the biological age of the arteries.

How is the procedure for measuring central aortic pressure performed?

Previously, determining CAT was possible only in a "bloody" way - using a probe inserted into the lumen of the aorta. Now devices have been created that

determine the level of CAT in the usual way - placing a cuff on the shoulder. This procedure is absolutely safe and painless and no different from a regular blood pressure measurement using an automatic tonometer. Before the study, height, body weight, shoulder circumference, and the distance from the sternum to the pubis are additionally measured.

SPIROMETRY

What is spirometry

Spirometry is a method of studying the functions of external respiration, which includes measuring the volume and speed of breathing. Spirometry helps to effectively determine the ability of the lungs to take in, hold and use inhaled air.

Such calculations are made using a spirometer - a special device that consists of an air flow sensor and an electronic device. The latter converts the sensor readings into digital form and performs all the necessary calculations. The patient inhales deeply and exhales with maximum force into the spirometer. The spirometer analyzes the air flow and processes the information received.

How is spirometry performed

Spirometry is quick and painless. During the spirometry test, the patient is in an upright position. He is given a spirometer and a disposable sleeve connected to a breathing tube. At the doctor's command, the patient takes a deep breath to completely fill the lungs with air, then exhales with the greatest force and for the longest possible time. At the same time, the spirometer measures and records the volume and speed of air passing through the device, as well as a number of other indicators. The procedure is usually repeated two or three times to establish the average value of all characteristics.

When to resort to spirometry

Spirometry is prescribed for:

• determining the severity of lung disease;

• monitoring the progression of lung disease;

• determining the nature of lung disease - restrictive (limits the flow of air into the lungs) or obstructive (disrupts the flow of air into the lungs);

• monitoring the effectiveness of treatment.

We use a modern digital spirometer Heaco SP10, which allows:

• quickly and comfortably assess the function of external respiration;

• conducting a study with a bronchodilator test;

• choosing the right dose of drugs;

• to estimate the studied parameters with high accuracy:

• FVC – forced vital capacity of the lungs;

• FEV1 – forced expiratory volume in the first second;

• FEV% – Tiffno index;

• PEF – peak expiratory flow rate;

• FEF – instantaneous volumetric velocities 25%, 75%, 25-75%;

• to obtain results in the form of tabular data and graphs.

The normal values of these parameters are individual, therefore the results of spirometry are evaluated by comparing them with the average statistical value for a

healthy person of the same sex, age, height and body weight. The presence and degree of restrictive and obstructive disorders are determined by the results of spirometry.

Spirometry results play a crucial role in the diagnosis of bronchial asthma, chronic inflammatory processes in the lungs and bronchi, and other diseases that can cause deterioration of lung function.

A decrease in many indicators by twenty percent or more from normal is considered a sign of impaired lung function, but in any case, the doctor makes a conclusion based on a comprehensive examination.

pH-metry is a method of studying the functional state of the upper gastrointestinal tract. It consists in measuring the acidity level (pH) directly in the esophagus, stomach, and duodenum using a special device - an acidogastrometer. This study is the gold standard of diagnosis, which allows you to put all the dots on it: to finally confirm this disease and treat it or to exclude it and look further.

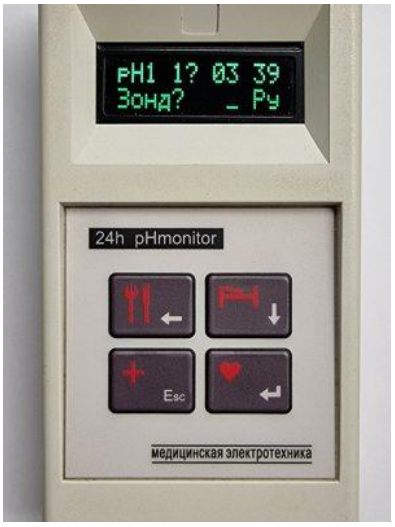
Acid reflux (reverse heartburn) is a normal physiological phenomenon if it appears on an empty stomach, and disappears after eating. But if the acid stays in the esophagus for too long, and the burning sensation does not go away, then this is a pathology that can even lead to cancer in the future.

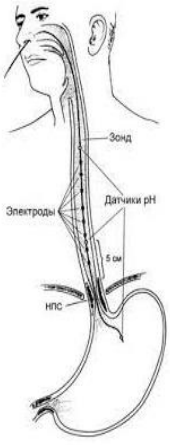
The symptoms of reflux disease are very similar to the symptoms of many other diseases:

- cardiovascular attacks,
- angina,
- chronic laryngitis,
- bronchial asthma,
- some neurological diseases, etc.

The patient may experience heartburn, but we do a pH measurement, and it turns out that he was treated by a gastroenterologist in vain. He does not have heartburn, there are no problems with the digestive system at all, but there are problems, say, with the heart. How to detect this? Very simple.

The procedure is performed by two methods: pH measurement - short-term study (within 4 hours) PH monitoring - daily (24 hours) study in a one-day hospital.





Pic. 70. pH measurement.

The essence of the study

We insert a wire with sensors through the patient's nose to a height of about 30 cm, approximately this is the place of the esophageal-gastric junction. We connect the wire to the device, fix it to the belt - that's it. The sensors perform their mission throughout the day: they detect acid reflux, distinguish between acid and alkali, because these reflux-refluxes can be different. This is a very smart system that analyzes what is refluxed there and how the acidity changes.

The patient adapts to the foreign body for half an hour and lives his usual life. Yes, he may feel a little nauseous, he may feel mild nausea, but this is a temporary discomfort that can be easily stopped in the clinic. Nausea - take anti-nausea drugs, a sore throat - suck on lollipops or drink tea.

The patient is in the clinic this day, while the diagnosis is ongoing, but he behaves as usual: he eats everything he likes, and from the food we give what usually causes heartburn. For example, he says that he likes Pepsi-Cola, and there is a reaction to it, then we bring him Pepsi-Cola to the ward. Everything that the patient does is necessarily recorded: he ate, drank, lay down, took medicine - he pressed a special button. He also notes his feelings: for example, his heart hurts - he presses a button, and the sensor analyzes whether it is related to reflux, or, perhaps, it is a psychological reaction.

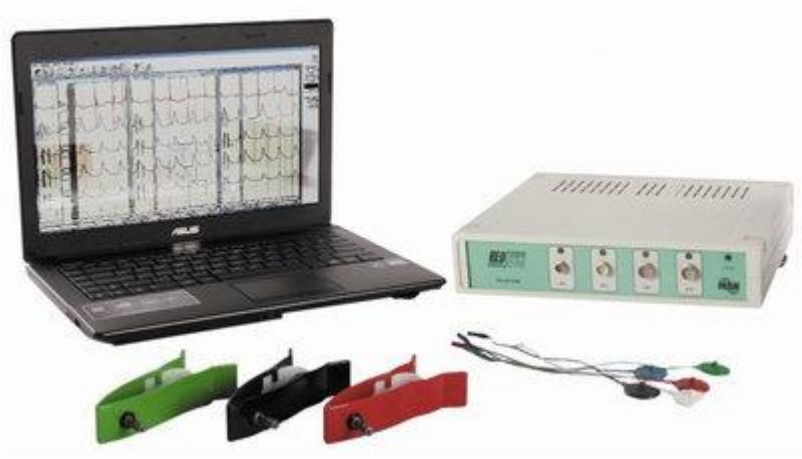
Research results

All data for the day are collected, then they are processed by a special program. We find out what kind of heartburn it is - is it acid or bile that is being thrown up, or, maybe, air, or, maybe, heartburn occurs because the patient lies down immediately after eating. We get a completely objective picture: there can be no subjective moments here. Next, the doctor finds out how the patient's feelings correlate with the data provided by Ph-metry.

After a full analysis, the patient is given recommendations. If the system shows that he lies down a lot during the day, his reflux is due to this, we recommend not to lie down for 3 hours after eating, if there are any specific products that cause heartburn, of course, we exclude them from the diet. This study helps to accurately determine the causes of the disease, and therefore choose the right treatment tactics.

Rheography (better known as **rheoencephalography** and **rheovasography**, as a method of diagnosing the state of blood flow in the human body appeared in the mid-60s of the last century, but today it has not lost its relevance, despite the advent of Dopplerography.

This method of research in full allows you to get answers to three important questions:

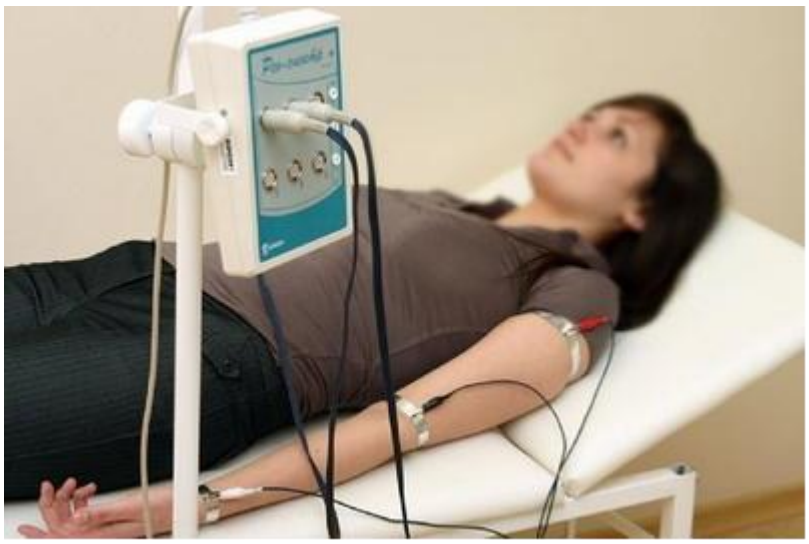


- is there a pathology;
- what is the nature of the pathology;
- what is the prognosis?

To do this, it is necessary to strictly adhere to the technology of performing the study, and not interrupt it at the stage of answering the first question.

Rheography is a diagnostic method in which blood flow is examined both in specific organs and tissues and in the entire organism as a whole. The essence of rheography is to graphically record, using a special rheograph device, changes in the electrical conductivity of the organ caused by pulse fluctuations in the blood flow. Among all the structures of our body, blood has the highest electrical conductivity. This means that during systolic contraction of the heart, when blood flows into nearby organs, the electrical conductivity of these areas of the body will be high, and at the moment of relaxation of the heart muscle (diastole), on the contrary - low. Based on the readings of the rheograph, a pulse oscillation curve is displayed, the so-called rheogram.

Rheography is a non-invasive method, which means harmless to the body. Indeed: no interference with its work occurs. The skin and tissues are not damaged, because the electric current passed through them has such a small magnitude and frequency that it is simply not capable of causing any tangible harm. Harmlessness is not the only advantage of rheography. This method has high sensitivity. Rheography allows you to assess the general state of blood supply, to detect blood supply disorders both in a separate organ, be it the brain, kidneys or liver, and in the whole organism.



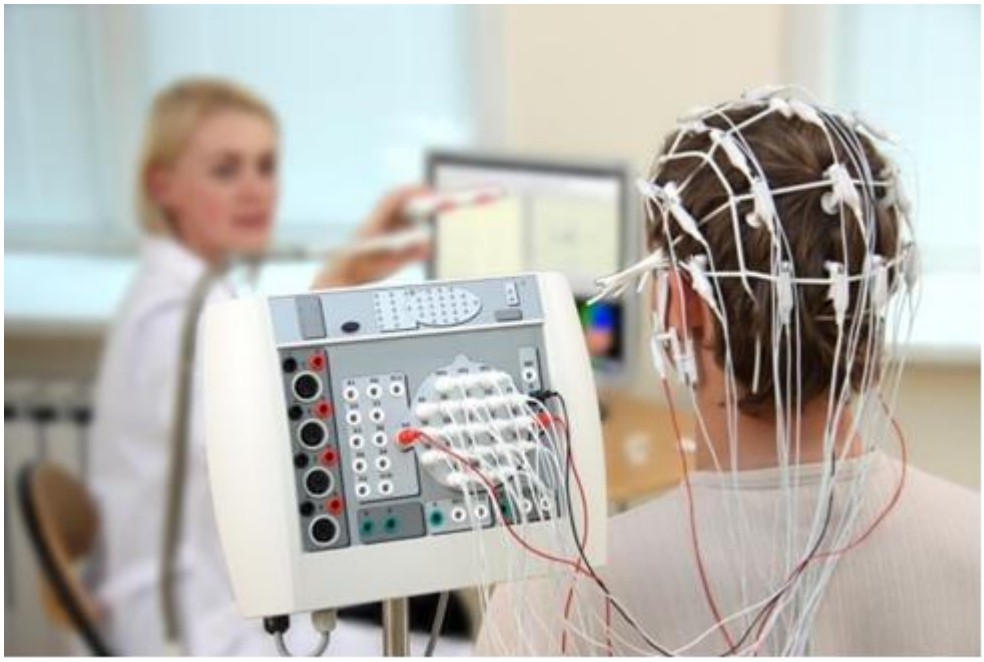
Pic. 71. Rheography.

RHEOVASOGRAM

Vascular rheography or rheovasography (RVG) allows you to assess blood flow in the vessels on the periphery, that is, in the extremities. The main "targets" of rheovasography are the vessels of the shoulder, forearm, hand (upper extremities), thigh, lower leg, foot (lower extremities). Vascular rheography is performed as follows: rectangular or strip electrodes are used, the skin under them is treated with a sodium chloride solution or a special conductive gel. To examine the blood flow in a certain area (shoulder, lower leg, etc.), one electrode is applied at the beginning of this area, and the other, respectively, at its end.

With the help of rheovasography, you can, for example, make a diagnosis such as obliterating endarteritis, or, as it is also called, "smoker's foot": a chronic disease in which the arteries of the lower leg and foot are affected. Thus, if there are prerequisites or suspicions of problems with peripheral vessels (loss of their tone, elasticity, narrowing of the lumen or even blockage), then vascular rheography will be able to answer the questions that concern you.

Rheoencephalography for children and adults



Pic. 72. Rheoencephalography.

It is also abbreviated as REG - this is a professional medical option for assessing and analyzing blood circulation inside the brain. REG allows you to get a lot of information about a person's health, as well as about the state of the brain both in areas and the entire brain as a whole.

Pediatric rheoencephalography (REG)

Rheoencephalographic examination is a simple and effective diagnostic method. Pediatric rheoencephalography with a high degree of probability and in a short time makes the correct diagnosis to the child. Rheoencephalography is a method of diagnostic research that allows you to analyze the most important criteria for the state of the brain vessels and the movement of blood through them.

Symptoms that require rheoencephalography for children:

- headaches;
- tinnitus;
- hearing loss;
- constantly high or low blood pressure;
- facial swelling;
- fainting;
- decreased visual acuity;
- cognitive changes;
- impaired coordination of movements.

Children are examined to monitor blood circulation after surgery, to determine the severity of hypertensive syndrome, head and neck injuries. Examination of the vessels of the brain helps to determine the presence of blood flow lesions in them, to analyze the effectiveness of certain medications and non-drug methods of therapy.

Pic. 73. Examination of the vessels of the brain.

Rheoencephalography is indicated in the following cases:

• Memory impairment
• Stroke
• Osteochondrosis
• Epilepsy
• Migraine
• Suspected ischemia
• Vertebrobasilar insufficiency
• Arterial hypotension
• Arterial hypertension
• Brain neoplasm
• Somatoform autonomic dysfunction of the nervous system (neurocirculatory dystonia)
• Hearing and vision disorders of unknown etiology

Contraindications

REG for children is an absolutely painless and safe diagnostic method. However, the study cannot be performed if the child has abrasions, wounds, purulent-inflammatory lesions, seborrheic dermatitis, lichen, etc. in the places of electrode application. Also, a contraindication to the study is the neonatal period.

Rheoencephalography for children is one of the most reliable diagnostic methods used in world practice. The study allows you to identify a variety of pathological conditions of brain structures, to establish the severity of the disease.

The basis of REG of cerebral vessels is the graphic registration of changes in the electrical conductivity of the brain vessels, provoked by fluctuations in the pulse of blood flow, as well as its speed in different vessels.

The examination is performed in a comfortable position - lying or sitting. Electrodes are attached to the areas of the intended study of the vessels. To conduct a better diagnosis, the child needs to be explained that during the procedure you need to try to completely relax.

A rheoencephalogram allows the child to study in detail:

1. The condition of the vessel walls.
2. The severity of blood filling and venous outflow.
3. Blood viscosity.
4. Blood flow speed, etc.

The decoding of the diagnostic results is quick, so specialists can make their conclusion almost immediately after the study. The examination procedure is quite quick and takes only 5-7 minutes.

VIDEOGASTERSCOPY

Videogastroscopy is one of the methods of endoscopic examination, and in our time, the most reliable method of examination of the gastrointestinal tract. This is a method that allows for a visual examination of the esophagus, stomach and duodenum, using a special tool - an endoscope.

The advantage is an accurate magnification of the image by several times, high expansion due to digital equipment, video examination in an enlarged form, with output to the monitor, which allows you to more clearly see the vascular pattern and the smallest changes in the mucosa.

This method of examination allows you to diagnose: inflammatory diseases of the mucosa, all types of gastritis, various formations (polyps, ulcers, erosions), bleeding, tumors.

Indications for gastroscopy:

- Peritoneal pain of unknown origin
- Discomfort in the esophagus
- Regular vomiting
- Swallowing disorders
- Unexplained weight loss
- Loss of appetite
- Unexplained anemia
- Pathologies of the pancreas, liver or gallbladder
- Preparation for surgery
- The presence of hereditary diseases (ulcers or stomach cancer)
- During medical check-ups for those who have been diagnosed with chronic gastritis or stomach ulcers
- To monitor the effectiveness of treatment for ulcers, gastritis or other pathologies
- After removal of a gastric polyp 4 times a year

During the examination, if necessary, material can be taken for biopsy (cytological or histological examination) to determine the morphology of the neoplasm (malignant or benign). And also to determine the presence of Helicobacter pylori - a bacterium that infects various parts of the stomach and duodenum.

The main goal of videogastroscopy is to prevent cancer. Timely screening allows you to detect precancerous conditions, as well as detect it in the early stages.

Videogastroscopy (FGDS - esophagogastroduodenoscopy, fibrogastroscopy) is the most accurate and informative method for diagnosing diseases of the esophagus, stomach and duodenum.

This procedure can be performed in a state of "drug sleep", which is performed by an anesthesiologist. In this state, the gag reflex disappears, which allows the doctor to enter the esophagus without hindrance and conduct an examination, and all unpleasant sensations are minimized. If the patient wants to be conscious, local anesthesia is used - an anesthetic solution. The time of this examination is 7-10 minutes.

The results of the examination are recorded on an electronic medium. This allows you to use these examination results for consultation with a narrow-profile specialist (gastroenterologist or surgeon).

VIDEOCOLONOSCOPY

Pic. 74. Videocolonoscopy.

Videocolonoscopy – used for accurate and complete diagnosis of colon pathologies. The procedure is as informative as possible. Videocolonoscopy makes it possible to examine the condition of the examined areas at high magnification on the monitor screen.

To conduct the study, a colonoscope is used – a flexible device, a Pentax ES38-i10L video gastroscope, a high-performance HD+ EPK-i7010 video processor with i-scan narrow-spectrum lighting mode, and a professional medical monitor "Pentax 27". It is used to diagnose a number of colon pathologies (Hirschsprung's disease, polyposis, ulcerative colitis, Crohn's disease, as well as the presence of malignant tumors, etc.). When conducting videocolonoscopy, a biopsy may be taken.

Colonoscopy in most cases is associated with not the most pleasant sensations. The procedure can be performed under medical sedation (under the supervision of an experienced and qualified anesthesiologist and only with an individual calculation of the dosage of the drug and its duration of action for each patient). This allows the doctor to obtain more information in a shorter period of time, and also improves the conditions for carrying out medical procedures. For the patient, performing a colonoscopy in a state of medical sleep (under anesthesia) allows the examination to be carried out as comfortably as possible.

Pic. 75. Colonoscopy in a state of medical sleep.

Indications for video colonoscopy:

• detection of palpable formations in the abdomen;
• mucus or blood in the stool;
• chronic constipation;
• causeless diarrhea;
• constant abdominal pain.

Preparation for the examination

In order for the study to be effective and as informative as possible, it is important to prepare for it correctly. Strict dietary restrictions should be observed:

• for 3-4 days, exclude vegetables, fruits, rye bread, nuts, mushrooms, jam, seeds, cereals (rice is allowed). You can eat white bread, mashed potatoes, dairy products, boiled fish, clear broths, chicken fillet, bananas, drink water, light juices, compotes without berries;

• for 2 days, you should switch to liquid food, do not take aspirin and iron-containing drugs. If defecation is difficult, do enemas or take laxatives;

• 1 day before video colonoscopy, a light breakfast is allowed. You cannot eat during the day and evening. You can drink clear drinks every hour and you need to move actively. From 6 to 8 pm, take 2 liters of Fortrans solution (1 glass within 15 minutes), drink it with clear juice or water;

• do not have breakfast before the examination, also take a second portion of Fortrans 5-6 hours before the examination and additionally 40 ml of Espumisan. If there is constipation, do an enema of Mikrolaks an hour before the procedure. Take two Buscopan tablets 4 hours before the procedure.

If general anesthesia (drug sleep) is used, it is important to be strictly on an empty stomach. A light breakfast is allowed if video colonoscopy will be performed under local anesthesia. The duration of the examination is from 10 minutes to 1 hour.

Contraindications to video colonoscopy

- Pulmonary and heart failure.
- Diseases of the hematopoietic system.
- Inflammation in the abdominal cavity.
- Exacerbated infectious diseases.
- Ischemic and ulcerative colitis.

Treatment during colonoscopy

During outpatient videocolonoscopy, polypectomy is possible - removal of polyps in the intestine with a diameter of up to 1 cm. A mandatory condition is the absence of contraindications in the patient. Thus, in the case of taking anticoagulants, the patient is recommended to stop taking the drugs 1 week before the colonoscopy in consultation with the doctor who prescribed these drugs.

VIDEOENDOSCOPY OF ENT ORGANS

Videoendoscopic examination of ENT organs is a modern, highly informative and completely harmless examination method. The method of endoscopy of ENT organs all over the world rightfully belongs to the gold standard of otolaryngology.

When examining ENT organs in the usual way, using a light source directed into the nose, throat, ears, unfortunately, most of the structures of the nose, nasopharynx remain inaccessible to the doctor's eye. The picture of the ear examination is also far from complete.

During visual examination, the pathology of the external auditory canal and the presence of inflammation of the eardrum are clearly visible, but the pathology of the tympanic cavity is often hidden. This pathology can be examined in detail only under magnification. The quality of endoscopic examination of all parts of the larynx, as well as the vocal cords and their mobility, is very different.

Videoendoscopic examination of ENT organs is an examination of the ear, throat, and nose using a special video camera with additional lighting and output of an enlarged image to a screen on which both the otolaryngologist and his patient will be able to see all the structures of the organ being examined from the inside.

The endoscope is a rigid or flexible thin optical tube that the doctor carefully inserts into the nasal cavity, ear canal, or brings to the entrance to the larynx. With the help of optics, the image is magnified several times. The video camera transmits the resulting image to a monitor.

Special otoscopic and rhinoscopic attachments are used - thin, cylindrical tubes with a diameter of less than 3 millimeters with a video channel and a light guide. The attachments do not heat up during the examination, their introduction is painless. The study does not require special preparation. If there is swelling in the nose before the diagnosis, vasoconstrictor drops are instilled into the nose in an age-appropriate

dosage to make the examination of the posterior parts of the nose and nasopharynx unhindered.

Videoendoscopic examination of ENT organs allows:

• To find out the exact cause of prolonged nasal congestion;

• To confirm or refute the presence of a tumor process in the cavities of ENT organs;

• To assess the condition and size of the adenoids;

• To examine the shape and size of the nasal turbinates, their patency;

• To examine the mouths of the auditory tubes, sinuses;

• To determine the nature of nasal discharge and their cause;

• To determine the condition of the vocal folds, subglottic and supraglottic regions, and upper parts of the trachea.

Endoscopy of ENT organs is performed using the latest equipment, so the procedure is painless and maximally informative. It does not require special training and takes no more than 10-15 minutes.

COLPOSCOPY

Colposcopy is a diagnostic method of examination that allows you to examine the cervix, vagina and external genitalia at multiple magnifications. Colposcopy allows you to detect precancerous conditions or cervical cancer, assess the size of the lesion, perform a targeted biopsy and take scrapings.

Indications

During the consultation, the gynecologist prescribes colposcopy for routine and differential diagnosis of pathological changes in the vaginal part of the cervix, the walls of the vagina and the vulva.

Indications for colposcopy:

• diagnosis of foci of pathological processes on the cervix that can be detected visually;

• deviations that were detected during the PAP test;

• positive result of the analysis for papillomatosis;

• detection of pathologically altered cells in the smear;

• detection of precancerous conditions and oncological diseases in the early stages;

• treatment of precancerous conditions of the cervix;

• monitoring the dynamics and effectiveness of the treatment;

• hereditary predisposition to oncology.

Colposcopy during pregnancy is an absolutely safe procedure that allows you to detect some pathologies of the cervix (erosion, inflammatory processes, etc.) in the expectant mother and prescribe the necessary treatment in a timely manner.

Pic. 76. Colposcopy during pregnancy.

All women over 18 years of age (provided they are sexually active) are recommended to undergo preventive screening for cervical diseases (colposcopy, oncocytological examination, etc.). Women over 40 years of age are recommended to undergo cervical colposcopy once every 6 months.

Contraindications

Colposcopy is an accessible and informative method of diagnosing the cervix, but nevertheless has some contraindications.

Contraindications to colposcopy

• acute inflammatory processes of the cervix;
• menstruation;
• allergy to iodine preparations and acetic acid solution.

Diseases

Colposcopy allows you to detect a wide range of diseases:

• Endometriosis of the cervix
• Erosion of the cervix
• Ectopia of the cervix
• Polyps and condylomas
• Precancerous conditions of the cervix
• Cervical cancer
• Inflammatory lesions of the cervical canal

Equipment

The latest video colposcope Scaner MK-200 allows you to diagnose the condition of the cervical mucosa with high accuracy. Thanks to the 16-fold magnification, the device allows you to detect pathology in the initial stages of its development. The device is equipped with a 10 W LED, which forms a high-brightness light spot. The image during the diagnosis is displayed on the monitor and can be saved on digital media in photo and video format, which allows the doctor to fully assess the picture of the pathology and select individual treatment.

Procedure

The examination of the cervix is performed in a gynecological chair, but lasts a little longer than a regular examination. First, ordinary vaginal speculums are inserted

into the vagina, after which an examination with a video colposcope is performed.

In gynecology, 2 main types of colposcopy of the cervix are used:

• Simple colposcopy.

Examination of the cervix is carried out without additional treatment with a dye. The study helps to establish the size and shape of the external pharynx, cervix, color and features of the mucous membrane, features of the vascular pattern, the "junction" zone - the border between the flat and cylindrical epithelium.

• Extended colposcopy.

It is carried out after treating the cervix with a special agent (acetic acid solution or Lugol's solution). It allows you to clearly diagnose pathological processes in the vaginal part of the cervix, determine areas for biopsy.

A modified type of extended colposcopy is chromocolposcopy. During it, the cervix is stained with various dyes. Differences in the color of the layers of epithelial tissue help to clarify the outer boundaries of the pathological process and its features.

Extended colposcopy includes examination of the cervix through yellow and green filters, under ultraviolet rays to detect clear contours of blood vessels.

Fluorescent colposcopy is an examination of the cervix in ultraviolet rays after staining it with fluorochrome. In severe oncology with necrosis and hemorrhages, complete extinction of fluorescence can be observed.

The most indicative method of examining the vaginal part of the cervix is colpomicroscopy, which allows you to enlarge the image almost up to 300 times.

Preparation for colposcopy

Preparation for colposcopy includes refusing sexual intercourse for the day before the examination, using vaginal contraceptives. Immediately before the examination, you need to empty your bladder.

TOPIC 6. NANOTECHNOLOGIES IN DIAGNOSTICS OF VARIOUS DISEASES

A correct diagnosis allows the doctor to quickly choose the necessary treatment strategy, increase its effectiveness, save his own time and the patient's health. Nanotechnology has become a revolutionary discovery for the world of medicine. The latest devices and systems that create materials the size of the smallest structural units of the body and will allow you to diagnose and stop diseases at the cellular level. The potential contributions of nanotechnology guarantee fast, highly accurate and affordable diagnostics that can be reproduced in real time at minimal cost. Nanotechnology will provide early diagnostics that will be the key to treating diseases with the highest mortality rate.

Nanotechnology is a set of methods and techniques that allow you to create materials with a given size and structure for manipulation at the molecular and atomic levels.

The specific diagnostic methods currently available are aimed at detecting antigens, enzymes, toxins and nucleic acids of the pathogen, especially popular methods are aimed at detecting the genetic material of the pathogenic agent, in

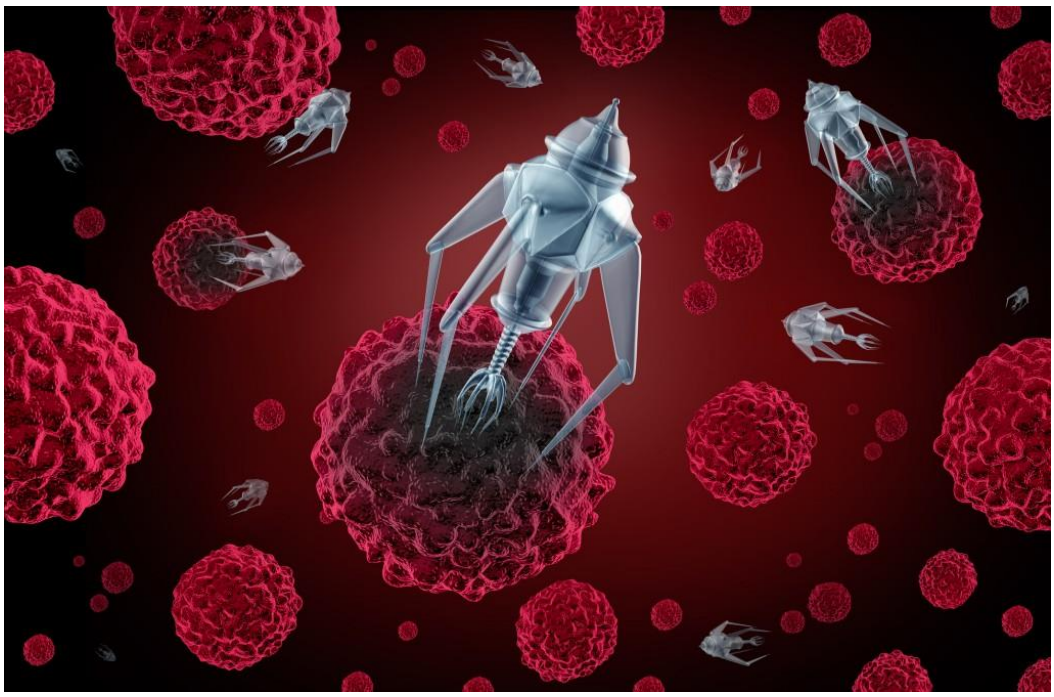
particular the extremely sensitive and specific polymerase chain reaction (PCR) method, molecular genetic. That is why scientists have turned their attention to nanotechnology, the following achievements and possibilities of nanotechnology are of particular interest for optimizing the diagnosis of infectious diseases:

- methods based on atomic force detectors, which significantly increase the sensitivity of research;
- the use of nanoparticles for rapid multiplex diagnostics in a small sample volume;
- spectroscopy methods based on Raman scattering of light using silver nanoparticles, which allow detecting trace levels of viruses in less than 60 seconds;
- nanotechnology on a chip - a system of complete chemical analysis, which allows for manual diagnostics, in particular using Cantileve technology (nanocantilevers allow for the creation of ultra-small sensors for real-time pathogen detection). It is everyone's dream to have a watch-microlaboratory for health monitoring on your wrist;
- introduction into practice of molecular detectors for reading single molecules of pathogenic agent proteins in the material under study, created, for example, on the basis of a nanowire located on the thinnest platform and thus forming a nanotransistor, on which receptor proteins are applied that are capable of specifically binding to biological macromolecules, which leads to a change in electrical conductivity indicating the presence of pathogen particles, the method allows for the detection of even a single virus and do it selectively;
- in conditions of limited amount of biomaterial it is advisable to introduce selective capture of pathogenic proteins on the surface of nanobiochips due to biospecific intermolecular interactions, thus separating them from low-concentration solutions and conducting further identification using an atomic force microscope;
- optical biosensors have become widespread in medicine - analytical devices used to "recognize" a molecule of biological material which, in the presence of molecules of a pathogenic agent, gives an electrical signal, it is recorded by devices operating on the basis of the effect of flood plasmon resonance and resonant mirror.

The advantage of nanodiagnostic tools is speed, high reliability, selectivity, the prospect of creating diagnostic devices accessible to everyone. These are methods that allow to determine specific proteins, RNA/DNA viruses or bacteria in biological material in a matter of minutes, which is especially important when establishing a diagnosis and for subsequent etiotropic therapy. It should be noted that the introduction of nanotechnologies into practical healthcare is not our distant future, these methods have been developed and refined by scientists, and in many countries they are already being put on stream.

Science does not stand still.

Technologies are developing rapidly and allow the creation of devices and programs that open up limitless possibilities in various fields of medicine. As a result, a person is getting closer and closer to understanding what is happening in his body not only at the cellular, molecular, but also atomic level - at the nanolevel.



Pic. 77. Atomic level - at the nanolevel.

Technology is developing at a rapid pace and allows you to create devices and programs that open up unlimited possibilities in various fields of medicine. As a result, a person is getting closer and closer to understanding what is happening in his body not only at the cellular, molecular, but also atomic level - at the nanolevel.

Here are 25 ways to use nanotechnology in medicine:

1. **Nanobots** are a generation of nanomachines of the future. They will be able to sense the environment and adapt to its changes, perform complex calculations, communicate, move, carry out molecular assembly, repair or even reproduce. These devices have great potential for use for medical purposes.

2. **Nanocomputers.** With their help, nanobots are controlled. Efforts to create nanocomputers, as well as the movement of quantum computing, are opening up new possibilities for medicine.

3. **Cell regeneration**. Damage to the body's cells is very difficult to repair due to the incredibly small size of the cells. However, with the help of nanotechnology, it becomes possible to circumvent this. Nanobots or other devices can be used to manipulate molecules and atoms at the individual level necessary for cell regeneration.

4. **Aging**. Nanodevices can be used to remove some of the signs of aging. For example, laser technology can reduce the appearance of age lines, spots, and wrinkles. In the future, powerful nanotechnology is planned to completely eliminate these signs.

5. **Cancer treatment**. To date, the first successful steps have been taken in the work on the use of nanotechnology in the treatment of cancer. This process is carried out due to the fact that the small specialized functions of some nanodevices can be

more precisely directed to cancer cells. In this case, the cancer cells are destroyed and the surrounding healthy cells are not harmed.

6. **Cardiovascular diseases**. There is a possibility that nanorobots can perform a number of functions related to the heart. Regeneration of damaged heart tissue is just one possibility. Another use of nanotechnology is to use nanodevices to clean arteries from atherosclerotic plaques and eliminate other problems.

7**. Implantation of devices**. Instead of implanting devices that are currently used in medicine, nanobots could be directed to create the necessary structures inside the body.

8. **Virtual reality**. Thanks to the use of injections of nanobots, it is easy for doctors to study the human body. The creation of virtual reality can help medical professionals make some operations more "realistic".

9. **Drug delivery.** Automated drug delivery systems contribute to increased coordination between the body's systems. At the same time, drugs are provided to the system that needs them. To ensure the release of certain medicinal substances at the right time and without human error, nanotechnology can be used to program delivery systems.

10. **Gene therapy.** Nanotechnology allows nanorobots to penetrate the body and make changes to the genome. This allows genome editing and, as a result, the cure of various genetic diseases.

11. **Nanotweezers**. These devices are designed to operate nanostructures. They can be used to move nanodevices around the body or place them before installation. Nanotweezers are usually built using nanotubes.

12. **Stem cells**. Nanotechnology can actually help adult stem cells turn into any type of cell needed. Studies in mice show that nanotubes allow adult stem cells to turn into functioning neurons.

13. **Bone regeneration**. Using nanotechnology, bone regeneration can be accelerated. Nanoparticles have different chemical compositions that can help connect bones together and can even help in some cases of spinal cord injury.

14. **Imaging.** Nanotechnology is very promising for use in the field of medical imaging, allowing you to quickly obtain an accurate, specific image. Nanodevices are used in molecular imaging and lead to improved diagnostics of various diseases and conditions.

15. **Diabetes.** Instead of taking blood to test blood sugar levels, nanotechnology allows diabetics to use lenses for this. The color change can be used to judge the blood sugar level.

16. **Surgery**. In the modern world, there are already robot surgeons, but nanosurgery is a promising field that can use some lasers, as well as nanodevices that can be programmed to perform certain surgical operations.

17**. Epilepsy**. Nanochips are being developed that can help manage seizures. These chips are designed to analyze brain signals, further analyze them, and make the necessary adjustments to the brain in such a way that it becomes possible to better control epileptic seizures.

18. **Sensory feedback**. Nanochips can be useful for people who have lost the ability to feel their body. To do this, nanochips intercept electrical impulses and interpret them.

19. **Prosthetic control**. Prosthetics continues to move forward. Nanotechnology allows you to control prostheses with the help of the brain. There are already some examples of using nanochips for this purpose.

20. **Medical monitoring**. With the help of nanotechnology, you can monitor the state of various body systems. Nanochips implanted in the body monitor the state of health and send the information received to a computer or other device.

21. **Medical reports**. In addition to monitoring the body's own systems, nanotechnology can be used to send information to healthcare providers, thereby increasing the efficiency of electronic medical records.

22. **Disease prevention**. The presence of a nanodevice in the body can really help prevent various diseases. With proper programming, it is possible to avoid some diseases and correct problems before they become serious problems. Nanodevices may even help prevent chronic diseases.

23. **Prenatal diagnosis**. There are several ways nanotechnology can be used in prenatal diagnosis. Nanodevices can penetrate the uterus and even the fetus without causing damage. In addition, they have the potential to help eliminate many problems in the womb.

24. **Personalized medicine**. By being able to precisely adapt to each person’s genome, nanotechnology will allow us to more accurately determine the appropriate treatment and tailor a treatment plan to the individual’s needs.

25. **Research**. Nanotechnology is enabling rapid advancement of medical research by providing the tools needed to learn about the structure and functioning of the human body, and through research in physics and chemistry, nanotechnology provides the body with building blocks.

MODERN MEDICINE IN NEW DIMENSIONS: TRANSLATIONAL AND PERSONALIZED, TARGETED AND INTEGRATED

The result of the review of the state of translational medicine in Ukraine is the certainty that there is a need to create new services and programs that ensure close cooperation between state, commercial and non-commercial organizations of our country, greater accessibility and transparency of new data for all researchers working in the field of invention translation. The creation and development of databases with various information on a large number of patients opens up wide opportunities for improving the quality of preclinical and clinical trials, and at the same time requires increasing their accessibility for researchers around the world. It is necessary to increase the use of the potential of social media and/or messengers to implement modern achievements of translational medicine into the clinical practice of our country, the medical community should receive educational programs, recommendations and support infrastructure in social networks. To form an effective scientific and educational environment, it is necessary to create a national Institute of Pharmacy and Translational Medicine. It is necessary to create and implement in the

educational pharmaceutical space of Ukraine an innovative educational program aimed at training specialists and research personnel of a new generation to work in various branches of the biopharmaceutical industry. It is advisable to create biological models of drug use, which allows testing dose-response effects and building pharmacokinetic models for specific environmental conditions, which will increase the predictive ability of test results when it moves to the stage of clinical trials.

The modern concept of personalized medicine is based on making medical decisions, using practices, interventions, products for the diagnosis, treatment and prevention of diseases, taking into account individual molecular-genetic and other variable phenotypic characteristics of the organism, individual tissues or/and cells.

Personalized medicine is an integral part of the innovative model of medicine of the future – "P5", which has five interconnected components

◆ Predictive – the use of laboratory and genetic tests, biomedical imaging methods, artificial intelligence, machine learning to predict the onset of the disease and the features of its course.

◆ Precision – the classification of patients with diseases into subgroups, taking into account their phenotypic multi-omic features.

◆ Personalized – the definition of individual interventions based on the genetic profile of each person, as well as taking into account other factors (patient abilities, context, needs, social status, lifestyle, family history, concomitant therapy and psychological aspects).

◆ Preventive – reducing the likelihood of disease occurrence by implementing preventive interventions taking into account biological, environmental (exposomal), social and psychological aspects of human life.

◆ Participatory – involving people in managing their health, through strengthening the capabilities, autonomy and involvement of patients and caregivers, as well as supporting communication between patients, doctors and those caring for them.

Currently, personalized medicine approaches are actively implemented in gastroenterology and dietetics, hematology, genetics, gerontology, dermatology, endocrinology, immunology and allergology, infectology, cardiology and rheumatology, neurology, oncology, ophthalmology, psychiatry, pulmonology and phthisiology, surgery and transplantology, in pharmacology, preventive medicine, etc.

Recommended literature

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Електронне навчальне видання комбінованого використання
Можна використовувати в локальному та мережному режимі

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ІСТРУМЕНТАЛЬНА ТА ЛАБАРАТОРНІ МЕТОДИ ДОСЛДІЖЕНЬ

Методичні рекомендації
для самостійної роботи студентів 2-го курсу медичного факультету
вибіркової з дисципліни «Інструментальні та лабораторні методи діагностики»

(Англ. мовою)

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